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ABSTRACT

A checklist of energy consumption reduction measures for universities is provided with the intent of achieving rapid and significant energy savings at minimal cost. Measures described should be within the scope of accomplishment by regular university operating and maintenance personnel. The measures involve non-technical actions such as adjusting temperatures and reducing lighting levels. Such action should result in reduction of at least 10%. Quick action measures are presented in 11 categories: (1) lighting; (2) heating and cooling; (3) ventilation and infiltration; (4) modification of central power plant operations; (5) electric power; (6) water heating; (7) elevators; (8) maintenance procedures; (9) water systems; (10) transportation; and (11) operating practices of kitchen and cafeteria areas. (RE)

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1971

Energy

Prepared by the Board of Regents, State of Kansas

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FOREWORD

The Board of Regents governs eight main campuses in Kansas at which over 74,000 students were enrolled in the fall semester of 1976. The physical plant comprises over 17 million square feet of floor space in 520 buildings. It will cost nearly eight million dollars in FY 1977 to pay for the energy necessary to operate these facilities. This expenditure will pay for 1.7 million gallons of fuel oil, 168 million kilowatt hours of electricity and 1.7 billion cubic feet of natural gas.

From fiscal year 1970 to 1979 utility rates will have increased 300% for electricity, 400% for oil and 500% for natural gas.

PREFACE

The primary purpose of this document is to provide a check list of energy conservation measures that can be implemented by the state institutions of higher education in Kansas that are governed by the Board of Regents. This document is also offered to Regents, Legislators, state officials and other interested persons as a summary report of action already taken or contemplated to reduce energy consumption.

Governor Robert Bennett has underscored the urgency with which Regents' institutions should implement energy conservation policies. In his message to the 1977 Legislature the Governor said, "Energy conservation projects at our state universities, including insulation, weather stripping, boiler improvements and the testing of energy conservation measures are a top priority. Energy losses in buildings under the control of the Board of Regents must be minimized."

As Chairman of the Board of Regents, I have strongly urged that the chief administrative officer of each of our institutions use every means within his power to implement the recommendations listed on the following pages.

This action has already saved thousands of dollars and will continue to save large amounts in the years ahead. I would again urge each institution to keep up the good work and try even more diligently to conserve fuel.

Thank you.

Walter Hiersteiner, Chairman
Board of Regents, State of Kansas

ACKNOWLEDGEMENTS

The Kansas Board of Regents wishes to acknowledge the help provided by the National Association of College and University Business Officers in preparing the data presented in Sections I and II of this document. The Board is also grateful to Architect Louis Krueger, Director of the Division of Architectural Services of the Department of Administration, for his help and permission to use his energy guidelines booklet as reprinted in Section III. Finally, the Board would like to thank the Association of University Architects and its architect members for their individual and collective help and assistance.

INTRODUCTION

The United States contains only 6% of the world's population but accounts for about 35% of the planet's total energy consumption. In the past few years there has been a very basic and fundamental change in the U. S. energy position. We have gone from an energy surplus to an energy deficit. For many years the American public felt it was entitled to as much low cost energy as it wanted and demanded. Being in the most energy-intensive nation on earth, our economy is the most dependent on and the most sensitive to variations in the energy markets.

Although it was the Arab oil embargo in October of 1973 and the subsequent "energy crisis" that brought public attention to our energy difficulties, these problems were inevitable. Before the year 1900 the primary source of energy in the United States was coal and our total annual energy use was less than five quadrillion BTU's. By 1920 our annual consumption increased to twelve quadrillion BTU's but our coal production was responsible for only 78% of that energy. In 1950 coal's share had been reduced to 38% of the total energy consumed and the total annual consumption had increased to almost thirty quadrillion BTU's. At the time of the oil embargo in 1973 our annual energy consumption was approaching seventy quadrillion BTU's and coal's share had declined to less than 20%.

In 75 years, although coal production remained relatively constant, coal changed from practically the only source of energy to a relatively minor source. During that period energy consumption increased about 1,600% and our nation became heavily dependent on petroleum and natural gas.

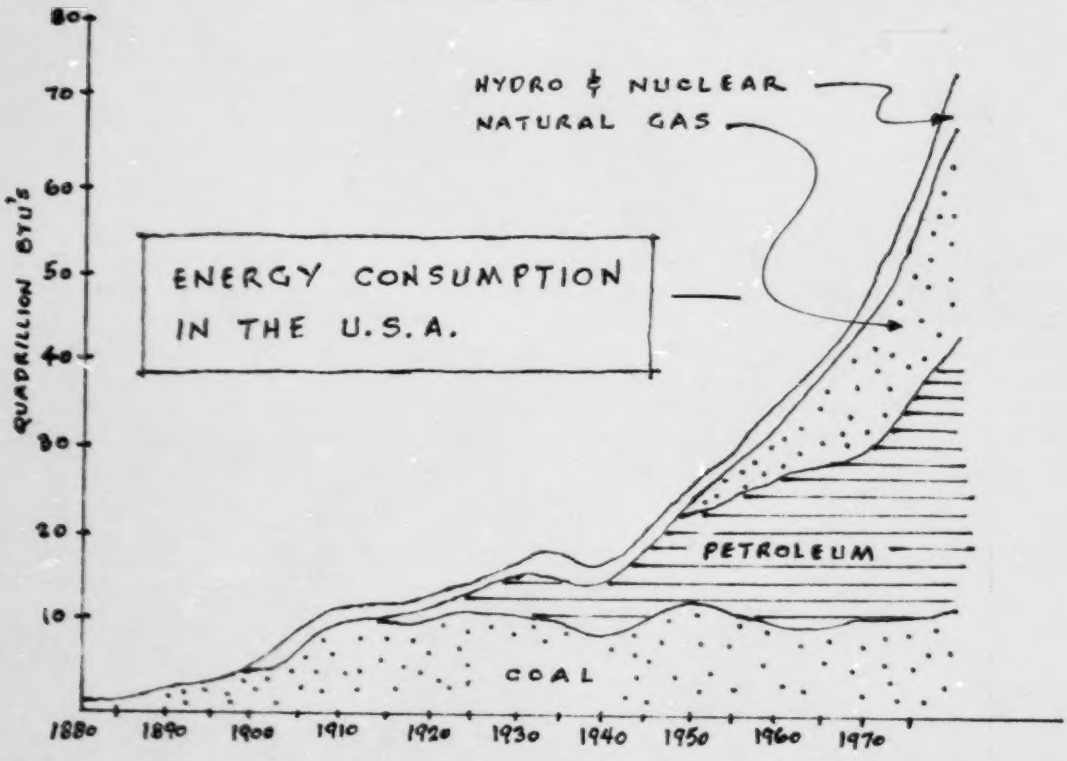
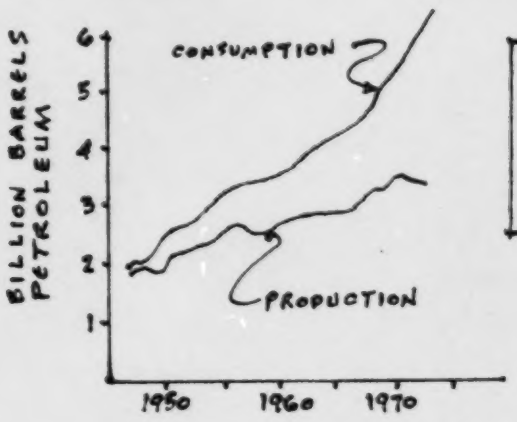


FIGURE 1

As a result of this vastly increased consumption of energy and this shift in primary fuel supply, a widening gap between domestic consumption and production has developed.



U.S.A. ENERGY PRODUCTION & CONSUMPTION

FIGURE 2

As a result the U. S. has become uncomfortably dependent upon foreign sources of energy. In fact, since 1960 reliance on imported oil has nearly doubled and since 1970 imported oil has accounted for virtually all increases in domestic energy consumption.

The cost of energy to the consumer will have tripled and quadrupled in this decade of the 70's. This has been a serious concern to our university campuses and a disruptive influence on their budgets. In 1974 the Board of Regents began to encourage the administrators of each campus to do everything in their power to conserve energy. Some of the Kansas legislators and especially members of the Ways and Means Committees began to encourage state institutions to save energy.

The universities have worked hard to conserve energy. Faculty, staff and students have been made aware of many ways to reduce energy usage. The following document includes a comprehensive checklist of energy consumption reduction measures that achieve rapid and significant energy savings at negligible cost. These measures have been or can normally be accomplished by regular university operating and maintenance personnel. These involve non-technical energy measures such as adjustment of temperatures and lighting levels which will quickly eliminate obvious waste and should result in reductions of at least 10%. These kinds of measures are often referred to as "quick-action" or "quick-fix" items.

Energy savings in excess of that created by "quick action" items usually involve refitting or converting of existing systems or spaces. Refitting and/or converting requires capital improvement funding and generally involves major changes or improvements in system design and operation.

SECTION I: QUICK-ACTION PROJECTS

Quick action measures can normally be accomplished easily and rapidly with very little capital cost. Minimal lead-time is required for their implementation if campus wide cooperation can be gained. To be effective some measures require the understanding and willingness of faculty, staff and students to turn off lights, pull drapes and perform similar functions requiring personal attention.

The quick action measures can generally be categorized into the following groups:

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LIGHTING

Reduce Lighting Energy Consumption

One of the most "visible" wastes of energy on the campus is lighting. Institutions have been over-illuminated with the result that excess energy is used both for lighting and fpr the cooling which is often necessary to offset the heat created by the lights. A variety of different steps can be taken to reduce the energy consumed by lighting systems:

- Establish illumination levels
- Establish usage program
- Remove unnecessary lamps
- Use more efficient lamps
- Improve maintenance

In all cases, however, it must be recognized that lighting serves very important purposes. Thus, while reduction of lighting is possible, such reductions should not be attempted at the risk of sacrificing the lighting required for comfort, safety and secruity.

Establish Illumination Levels

One of the first things which should be done in any effort to reduce lighting levels is to conduct a lighting survey in order to establish where lighting is used, what quantity/quality is used and when it is used. In some cases, for example, it may be shown that the lighting system design and controls are completely adequate for building use during normal occupancy periods. However, if the building frequently is occupied after normal occupancy periods--as often is the case in buildings which house computers and related data processing equipment--significant wastage may occur because controls do not permit a high level of selectivity during off-hours. Therefore, all data on lighting systems and building usage must be on hand so decisions regarding lighting system modifications can be made in an informed manner.

Existing lighting levels in standard footcandles can be determined with portable illumination meters. Generally, measurements refer to average maintained horizontal footcandles at the task or in a horizontal plane 30 inches above the floor.

In most buildings there are three general categories of illumination required: specific task lighting, general lighting around tasks, and general lighting for circulation and support areas.

Recommended illumination levels for various uses and occupancies provided by the Illuminating Engineering Society are shown in Figure 3.

Figure 3

RECOMMENDED LIGHTING LEVELS

The Illuminating Engineering Society recommends the following lighting levels for various uses and occupancies:

ILLUMINATION LEVELS

	Minimum Foot Candles
Libraries	
Reading Rooms and carrels	70
Stacks	30
Book Repair and Bindings	70
Check in & out, catalogs, card files	50
Offices	
Designing, detailed drafting	110
Accounting, bookkeeping and business machines	85
Regular office work, reading, transcribing, active filing and mail sorting	70
Corridors and stairways	20
Washroom	20
Classroom Space	
Regular classroom work	50
Chalk boards	100
Drafting rooms	100
Auditoriums	
Assembly only	20
Study Hall	50
Laboratories	
General Work	50
Class work	100
Lecture Rooms	
General	50
Special/demonstration/exhibit	100
Domitory Rooms	
Concentrated and prolonged study	50
Lounge/Lobbies	10
Kitchen	30
Exterior	
Parking areas	5
Roadways	5

The Federal Energy Administration has developed similar standards of its own, as shown in Figure 4.

Figure 4

FEA RECOMMENDED MAXIMUM LIGHTING LEVELS

Task or area	Footcandle levels	How measured
Hallways or corridors	10 ± 5	Measured average, minimum 1 footcandle
Work and circulation areas surrounding work stations	30 ± 5	Measured average
Normal office work, such as reading and writing (on task only), store shelves, and general display areas	50 ± 10	Measured at work station
Prolonged office work which is somewhat difficult visually (on task only)	75 ± 15	Measured at work station
Prolonged office work which is visually difficult and critical in nature (on task only)	100 ± 20	Measured at work station
Industrial tasks	ANSI-A11.1-1973	As maximum

Once desired illumination levels are established, it is possible to determine what changes can be made to achieve such levels with the least expenditure of human energy and funds.

Establish Usage Program

The key element of a lighting usage program is a schedule which relates to occupant use patterns. Surveys should be conducted to determine the amount of lighting needed for task performance, safety and security in a given space for specific periods of time, such as occupied hours, evening hours, weekend/holiday hours, etc. Having a lighting schedule is especially important for periods when a building or space is occupied primarily by maintenance and/or custodial personnel. In many cases, lighting on an entire floor will remain on while custodial personnel move from area to area. By developing a schedule, informing personnel, and assigning lighting control responsibility, it is relatively easy to ensure that such wastage is reduced if not eliminated altogether. The lighting usage progam may be made even more successful when some of the following suggestions are utilized.

Identification Switch

Switch identification can be accomplished by posting small labels or signs which identify luminaires controlled by the switch. Color coding of switches can also be used.

Better Lighting Use Campaign

A campaign for more effective use of lighting can also be mounted. Through such mechanism as personal contact, memoranda and signs which encourage people to use only the illumination required for a task or function and to de-energize luminaires whenever they are not needed, further savings can be achieved. In many cases preprinted labels can be affixed to light switches, encouraging de-energization after use.

Remove Unnessary Lamps

When removing fluorescent or high intensity discharge lamps, it is important to remember to also remove the ballast (or disconnect it in place). If the ballast is left connected to the power source it will continue to consume energy even though it serves no useful purpose. When two-lamp fluorescent fixtures are mounted in a row, remove the lamps in alternate fixtures of the rows. However, in order to maintain the recommended lighting level it may be necessary to use increased output lamps in place of some of the remaining lamps. Even so, the measure should result in net savings of energy.

Use More Efficient Lamps

Lamp efficiencies vary between lamps consuming the same number of watts and between lamps of the same type.

Efficiencies range from less than 23 lumens per watt to more than 180 lumens per watt. Most manufacturers have developed new types of lamps designed specifically for refitting existing fixtures. For example, reduced wattage fluorescent lamps which operate on standard CBM ballasts are now available. These lamps use less energy, provide more lumens per watt, are interchangeable

with other lamps, provide the user with a choice of wattage, and maintain light distribution and lighted appearance. Reduced wattage fluorescent cool white lamps are available in a four-foot rapid-start version rated at 35 watts, 2,850 lumens and 20,000 hour life as compared with a standard four-foot, RS rated 40 watts, 3,150 lumen, and 20,000 hour life. Also available is an eight-foot, slimline version, rated at 60 watts, 5,600 lumens, and 12,000 hours life as compared with a standard eight-foot, slimline, rated at 75 watts, 6,300 lumens, and 12,000 hours life. In addition, reduced wattage HO (high-output) fluorescent lamps have been recently introduced. Incandescent lamps have the poorest efficiency of all.

A. Turn Off Lights

1. Mark all ganged switches with identification indicating the lights controlled. Color code switches and institute a program of effective lighting usage.

2. Instruct occupants and maintenance personnel to switch off all lights which are not required.

3. Turn off all lights other than those needed for security and egress when the building is unoccupied.

4. Substitute small table or floor-mounted lamps in lounge area or waiting rooms and turn off modular ceiling fixtures.

5. For cleaning which must be done after daylight, turn on lights only in that portion of the building which is being cleaned immediately.

6. Turn off flood lighting which is strictly decorative.

B. Utilize Daylighting as Practicable

1. Clean windows and skylights.

2. Where practical, schedule cleaning and meetings during periods of building occupancy to make maximum use of daylight.

3. Locate tasks that need the best illumination closest to the windows, with the task-viewing angle parallel to the windows.

4. Switch off electric lights in areas when natural light is available.

5. Increase the inter-reflectances of interior surfaces. Utilize light colors for walls, ceilings, floors, rugs, furniture and draperies.

6. To reduce glare, rearrange work stations so that side wall daylight crosses perpedicular to lines of vision.

C. Improve Maintenance

1. Light output should be checked regularly with a calibrated light meter by maintenance personnel. When the light output of a group of lamps has fallen to approximately 70 percent of the original light output, relamp all fixtures in the group at the same time. This is also a good time to check whether a more efficient or lower wattage lamp is suitable.

2. Lamps should be wiped clean at regular intervals to assure maximum efficiency. Lamps which are exposed to an atmosphere with substantial amounts of dirt, dust, grease, or other contaminants should be cleaned more frequently than lamps in a relatively clean atmosphere.

3. Luminaire efficiency can be maintained by properly cleaning reflecting surfaces and shielding that has yellowed or become hazy with a clear acrylic lens with good non-yellowing properties. For some applications, a clear glass lens can be considered if it is compatible with the luminaire and does not present a safety hazard. (Caution should be used to assure that an existing luminaire will safely support and hold the glass lens.)

4. Clean ceilings, walls and floors frequently to improve reflective qualities. When daylight is used, wash windows frequently to maintain illumination levels on tasks which require some natural illumination.

D. Modify Illumination Levels

1. Illuminate specific task areas to that level, for each area, which provides adequate lighting to perform the required task satisfactorily and reduce illumination levels to adjacent areas. Follow recommendations detailed in Section III.

E. Remove or Replace Lamps

1. Remove unnecessary lamps if removal will still enable provision of illumination levels required. When lamps are removed from a fluorescent luminaire, all lamps controlled by a given ballast should be removed to prevent ballast failure or reduced lamp life. Except in the case of instant-start lamps or luminaires with circuit-interrupting lamp-holders, also consider disconnecting ballasts which otherwise would continue to consume energy.

2. Consider replacing present lamps with those of lower wattage which provide adequate illumination. Be certain that new lamps are compatible for use with existing ballasts in fluorescent and HID (high intensity discharge) luminaires.

3. Use a single, larger incandescent lamp where possible, rather than two or more smaller lamps. Higher wattage general service incandescent lamps are more efficient than lower wattage lamps.

4. Avoid multi-level lamps. The efficiency of a single wattage lamp is higher per watt than a multi-level lamp.

5. Avoid using extended service lamps except in special cases, such as recessed directional lights, where short lamp life is a problem.

6. When relamping, replace 40-watt fluorescent lamps with 35-watt lamps to achieve a reduction in lighting level of approximately 18 percent, while saving 20 percent in fixture electrical energy.

HEATING AND COOLING

Shut Down Building Heating, Ventilating, and Air Conditioning Equipment During Unoccupied Periods

Substantial savings can be achieved by providing a well-planned unoccupied shutdown cycle during periods when a building has few or no occupants. Examine the building for actual utilization patterns and determine ways to permit maximum shutdown of energy-consuming equipment during these periods. Experience has shown that only a small portion of a building actually requires night or 24-hour operation. Often a small unitary air conditioning system designed to serve a room or few rooms will permit substantial shutdowns of large central systems. If central air systems are required in order to provide the only source of heat for a building during the rare occasions when the building is used at abnormal hours, a low-limit night thermostat can be provided to start the system on a full heating mode with all outdoor air dampers closed in order to operate as required to keep the building at 60° F if that is the desired temperature.

The low limit night thermostat is controlled by a time clock which, at a preselected hour, starts and stops selected fan units and/or opens or closes automatic water or steam valves to maintain the desired temperature. However, it is surprising how infrequently this type of unit will actually be required to operate in many buildings since many university buildings have a large thermal storage capacity and thus lose temperature very slowly.

Separate convector or radiation hot water systems in buildings normally can provide adequate heat during unoccupied periods without operating large central supply air systems. These radiation systems can often be completely shut off at temperatures of 35 to 45 and above depending on the building envelope involved, the amount of glass, wall construction, etc.

When the HVAC system is de-energized during unoccupied periods, it is essential to keep outside air dampers closed tightly. Inspection of dampers to be sure that there is a tight seal and repair as required are important. Exhaust fans which interlock with outside air fans should also be closed. The only exceptions to these guidelines would occur when using an economizer cycle at night during the cooling season. An economizer cycle is one that uses cooler outside air to lower indoor temperature in place of a mechanical cooling system.

Although shutdown during unoccupied hours seems an easy and obvious step, it simply was not done during pre-energy awareness days. As a result, the savings to be obtained are substantial. One major university cut its gas and electric bill by almost 28 percent for an annual savings of close to $34,000 in just one building, an agricultural facility with no laboratories. This university programmed its start-up and shut-down in accordance with the needs and typical occupancy patterns of the various buildings involved. This programmed schedule can be followed either through manual or automatic activation of controls. It is also worth noting that the schedule developed by this university calls for sequencing the start-up of HVAC equipment to minimize electrical demand. In some cases refitting of a system will be required in order to gain the type of control which will allow programming for an unoccupied period. That is, it may be necessary to spend some money to install equipment which will deactivate a system which was not designed for starting and stopping. However, such refit modifications will generally lead to very fast paybacks.

Add a Warm-Up Cycle

When dealing with air handling units with outside air intake, it is advisable to incorporate a "warm-up" cycle into the system. The purpose of the cycle is to keep the outside air dampers closed during morning warm-up or cool-down. Only heating and cooling of the air already in the building would then be required, eliminating the need to treat the air that would normally be brought in through the open ventilation system. A two-circuit time clock usually is provided to control the outside air damper and fan operation.

Reset Mixed Air Temperature in Terminal Reheat Systems

Terminal reheat systems are very popular because they allow a high degree of temperature and humidity control. Nonetheless, terminal reheat systems waste energy. Supply air is passed through cooling coils which reduce temperature to approximately 53°F. The cooled air then flows by ducts to each of the spaces served. Prior to entering the space the cooled air passes through a terminal heating coil, which then raises the air temperature to achieve the thermostatic setting in the space involved.

The techniques utilized by one major university to minimize the energy consumption of terminal reheat systems are worthy of note and implementation.

In the summer months, the reheat coils were de-energized completely. The return, outside air, and mixed air dampers were adjusted manually so that air was circulated at a constant temperature from 60°F to 70°F depending on building characteristics and the heat generated by its occupants. However, because of load fluctuations, systems in some buildings had to be adjusted frequently--as much as twice a day. In one full summer of operation on this pattern, it was found that the temperature and humidity levels in most spaces were completely satisfactory. The result was a reduction in cooling load of 40 to 50 percent for the summer involved.

During the winter months, the outside air and return air dampers were adjusted slightly so supply air temperature was between 64°F and 70°F, depending on the conditions in the area served.

This technique has been used by many other universities and facilities. It is important to be aware, however, that in some cases--such as when a system is serving a computer room--temperature and humidity conditions must be maintained within certain specified limits. In such cases, adjustments to a terminal reheat system must be made with extreme caution.

Reset Deck Temperatures in Dual Duct Systems

The constant volume dual duct system is similar to the terminal reheat system. The difference is that each space is provided with both heated and cooled air which--before entering the space--passes through a mixing box which mixes the heated and cooled air to attain the desired temperature.

The same university mentioned above has also modified its dual duct systems in a very effective manner. During winter months, the temperature of the cold air is allowed to rise to 60°F to 70°F by adjusting the outside air and return air dampers.

During summer months, by using cooled air at 64°F instead of 53°F, much less heating energy is required to attain desired temperatures.

Dual duct systems, like terminal reheat systems, are used to achieve a high degree of control over temperature and humidity. In cases where tight control is required, adjustments must be made with extreme caution.

Reduce Ventilation Rates during Occupied Periods

The amount of outdoor air which is introduced into a building for ventilation by mechanical systems is perhaps the single most important factor that influences a building's heating load in winter and its cooling load in summer. Each cubic foot of air brought into the building must be either heated or cooled and then humidified or dehumidified to meet indoor conditions.

Many buildings are ventilated at a rate far in excess of that necessary to maintain comfort, or to dilute odors and meet code requirements.

There are three things to consider prior to adjusting ventilation rates:

A. Determine current ventilation rates by measuring the volume of air at the outdoor air intakes of the ventilation system.

B. Determine typical occupancy patterns for the building involved. During what days of the week and what hours of the day is peak occupancy reached and how many people are involved?

C. Determine fresh air code requirements for the facility involved.

Reduction of ventilation rates to the minimum possible, usually about five cubic feet/minute/person is desirable. Most buildings have ventilation rates in excess of code requirements even though it is generally recognized that codes themselves call for more ventilation than required. Accordingly, first determine whether ventilation rates meet code specifications by becoming familiar with code requirements and by measuring ventilation rates. Ventilation rates may be measured by using an anemometer at the outdoor inlet or louver to measure the amount of outdoor air introduced into the ventilation system. Remember that the outdoor air damper setting often differs from the damper indicator setting. Also, realize that a hinged volume damper blade does not proportion air directly with its opening. A blade with a 10 percent opening permits much more than 10 percent flow.

If ventilation rates can be lowered without going below code requirements, reductions can be achieved by closing outdoor air dampers until the desired volume is flowing. Thus it is important to adjust outdoor air, relief air, and mixed air dampers for proper operation in order to bring in the desired minimum volume of outside air.

Also consider cycling a ventilation system by turning it off every 20 minutes or so and letting the building "coast." Obviously, where certain types of research are involved, this practice must be approached with caution.

Reduce Exhaust Hood Use

Exhaust hoods which are used in kitchens, medical and research buildings, laboratories, etc., consume energy as a result of the energization of exhaust equipment. More important, however, is the indirect energy consumption of this equipment. Every cubic foot of air exhausted must be replaced or "made up" by outside air which, in turn, must be conditioned, heated, cooled and humidified or dehumidified by mechanical systems.

A typical fume hood requires make-up air which consumed energy equivalent to that required to heat one four-bedroom home or to cool two four-bedroom homes annually. The most obvious method for cutting back the energy required for make-up air is to reduce hood use to a bare minimum. Generally speaking, developing a schedule for hood use will be very helpful. Those who work in spaces where hoods are used probably can assist by suggesting time changes and modifications.

I. Modification of General Operating Practices

A. Shut down cooling equipment at nights and during days when the building is unoccupied.

B. Install warm-up cycle controls on airhandling units with outside air intake to permit outside air dampers to remain closed during building warm-up or cool-down.

C. Reduce use of heating and cooling systems in spaces which are used infrequently or for short periods of time.

D. Cool office, general purpose, academic and residential buildings to 80°F. Special considerations should be given to computer rooms and research areas due to process and health requirements. (Each degree raised is a 5% reduction in electrical consumption.)

E. Begin precooling operations so the building is at 80°F when occupants arise. Complete cool-down during the first hour of occupancy.

F. Heat general purpose and academic buildings to 68°F when occupied, to 60°F when unoccupied. This does not mean that air should be cooled if the temperature exceeds 68°F. (Each degree lower will result in a 3% reduction in energy consumption.)

G. Consider the following guidelines for heating temperature setback during unoccupied periods.

   1. Shut off radiators or registers in lobbies.

   2. Adjust automatic timers or add time clocks for night and weekend operation for all areas occupied infrequently.

   3. When buildings are used after hours for meetings, conferences, cleaning, or scattered activities, reduce the number of spaces occupied and, to the extent possible, consolidate activities in the same section of the building. Also reduce temperature and turn off humidifiers.

   4. When there is no danger of freezing, turn off radiators or supply registers in areas that do not have a separate thermostat. Open them when building is occupied.

   5. Check relevant codes requiring protection for plumbing, fire sprinkler systems, and standpipes before implementing extreme temperature reduction. Public utilities may set temperature requirements for their equipment rooms.

H. Advise occupants to wear heavier clothing when indoor temperatures are lowered.

I. In large heated areas such as storage spaces that are occupied by only one or two people, reduce temperatures to a level just sufficient to prevent damage to other systems (plumbing, sprinkler systems, etc.). Consider local radiant heaters instead of central heating systems.

J. Evaluate the necessity of humidification systems and curtail humidification in lobbies, corridors, laundries, cafeterias, kitchens, etc., where equipment or process requirements do not take precedence.

K. Allow natural humidity variation in occupied spaces.

L. Turn off all humidifiers at night and during unoccupied periods.

M. Turn off portable electric heaters and portable fans when not needed and during unoccupied periods.

N. Turn on self-contained units, such as window and through-the-wall units, only when needed. Turn them off when the space is to be unoccupied for several hours.

O. Turn off reheat in all areas during summer, except where equipment requirements necessitate humidity control.

P. When the sun is not shining during the heating season, close interior shading devices to reduce radiation from body to cold window surfaces.

Q. Develop an after-hours equipment operation check list for use by custodial and other building personnel as well as occupants who may use various spaces after normal periods of occupancy.

R. Schedule operating and maintenance work during the daytime, if possible.

S. Reduce internal heat generation as much as possible during the cooling season. Typical sources of heat generation include lighting, people, machines, and cooking equipment.

T. Turn off heat in store rooms and closets. Close off heat in unoccupied spaces and reduce heat to a minimum.

U. Do not attempt to maintain the same comfort conditions in corridors as that of offices and classrooms.

V. Make certain all entrances, exits and corridor doors are not propped open during heating or cooling cycles.

W. Use cool night air to flush buildings in the summer.

II. Modification of HVAC System Operating Practices

A. Terminal Reheat System--methods which make systems more energy efficient:

1. De-energize or shut off reheat coils and raise chilled water supply air temperature in summer months in increments of 3 F to determine the highest supply temperature which will maintain satisfactory room conditions. Temperatures which some universities have found suitable range from 60° to 70°F.

2. Reduce supply air quantity.

3. Adjust outside air, return air, and mixed air damper controls in winter to raise supply air temperature to a level between 64° and 70°F, depending on conditions in the area served by the system.

4. If close temperature and humidity control must be maintained for equipment purposes, lower water temperature and reduce flow to reheat coils. This will still permit control, but will limit the system's "energy requirements".

B. Dual Duct System

1. Refer to "Terminal Reheat System" for general recommendations applicable to dual duct system.

2. Lower hot deck temperature and raise cold deck temperature.

3. Reduce air flow to all boxes to minimally acceptable level.

C. Multizone System

1. Set controls to reduce hot deck temperatures and increase cold deck temperatures, consistent with the loads of critical zones. While this will lower energy consumption, it also will reduce the system's heating and cooling capabilities as compared with current levels.

D. Induction System

1. Refer to "Terminal Reheat System" for general measures also applicable to Induction System.

2. Inspect nozzles. If metal nozzles, which are common on most older models, are installed, determine if the orifices have become enlarged from years of cleaning. If so, chances are that the volume/pressure relationship of the system has been altered. As a result, the present volume of primary air and appropriate nozzle pressure required must be determined. Once done, rebalance the primary air system to the new nozzle pressures and adjust individual induction units to maintain airflow temperature. Also inspect nozzles for cleanliness. Clogged nozzles provide higher resistance to air flow, thus wasting energy.

3. Set induction heating and cooling schedules to minimally acceptable levels.

4. Reschedule the temperature of heating water and cooling water according to load. Avoid simultaneous heating and cooling in any one zone.

5. Schedule the temperature of the primary air supply in air handling units according to load. Achieve modulation preferably by adjusting water temperature. This modification may result in wet coils at induction units and increase maintenance.

6. For operation during unoccupied hours in the heating season, shut down primary air fans, raise the hot water temperature, and operate induction units as gravity convectors.

E. Single Zone System

1. Implementing energy conservation measures which reduce the heating and/or cooling of air handled by the HVAC system will result in reduced fan power input requirements. Fan brake horsepower varies directly with the cube of air volume. Thus, for example, a 10 percent reduction of air volume will permit a reduction in fan power input by about 27 percent. This modification will limit the degree to which the zone serviced can be heating or cooled as compared to current capabilities.

2. Raise supply air temperatures during the cooling season and reduce them during the heating season in accordance with thermal needs. Adjust chilled water and hot water temperatures to provide advised supply air temperatures.

3. Avoid simultaneous heating and cooling except as required for humidity control in critical areas.

F. Fan Coil System

1. Refer to "Single Zone System" for general recommendation applicable to fan coil system.

2. When heating and cooling loads are minimal, shut off fans to enable the coil to act as a convector.

3. Consider installing interlocks between the heating and cooling coils of each unit to prevent simultaneous heating and cooling.

4. Block off outdoor air inlets where no dampers are installed if infiltration meets ventilation requirements.

G. Constant Volume System

1. Determine the minimum amount of airflow which is satisfactory and reset the constant volume device accordingly.

2. Investigate the possibility of converting the system to variable (step-controlled) constant volume operation by adding the necessary controls.

H. Variable Air Volume System

1. Reduce the volume of air handled by the system to that point which is minimally satisfactory.

2. Lower hot water temperature and raise chilled water temperature in accordance with space requirements.

3 Lower air supply temperature to that point which will result in the VAV box serving the space with the most extreme load being fully open.

4. Operate variable volume reheat systems in a manner similar to that described for terminal reheat.

I. Self-Contained Systems

1. Turn off cooling units and fan when leaving space.

2. Install timers to shut units off automatically.

VENTILATION AND INFILTRATION

A. De-energize outdoor air supply fans during unoccupied periods. Use an automatic timer if one is available or switch off manually. If an automatic damper is supposed to close when the fan shuts down, check to make sure it closes tightly. Repair it with felt edges or other suitable material if it by-passes air.

B. Provide general ventilation in accordance with occupancy, not on a continuous basis. In many buildings heavy occupancy occurs at regular intervals so ventilation can be shut off for certain periods during the day.

C. If windows are used to provide ventilation, be sure they are closed at night.

D. If air handling units which supply heated or cooled air are equipped with outdoor air inlet ducts and dampers, close dampers during unoccupied periods. If no damper exists, install a felt-lined one with a remote or local control device and timer control.

E. When not operating on economizer cycle, close outdoor air dampers for the first and last hours of occupancy if outdoor air has to be heated or cooled.

F. Shut off exhaust fan hoods in laboratories, kitchens, bakeries and cafeterias when operations are completed. Add control damper or gravity damper to keep the air path in the exhaust duct closed when fan is not operating.

G. Outdoor air quantities for window units, through-the-wall units and fan coil units generally are fixed. When these units are used to maintain nighttime or unoccupied cycle room temperatures, the outdoor air intakes are generally open. If dampers are available, close them when outdoor air is not needed. Where infiltration is sufficient for daytime ventilation requirements, block off the outdoor air damper completely for some or all of the units.

H. Reduce ventilation rates during occupied periods to a minimum possible, usually about 5 CFM per person.

I. Check codes, where applicable, for specification of minimum exhaust CFM and for rules on recirculation or filtering of air.

J. Use an anemometer or other flow meter at the outdoor inlet or louver to measure the amount of outdor air introduced into the ventilation system. The outdoor air damper setting often differs from the damper indicator setting. Also, realize that a hinged volume damper blade does not proportion air directly with its opening. A blade with 10 percent opening permits much more than 10 percent flow.

K. Cut off direct outdoor air supply to toilet rooms and other "contaminated" or potentially odorous areas. Permit air from "clean" areas to migrate to the "dirty" areas through door grilles or undercutting of doors. This is effective if toilet areas have a mechanical exhaust system, or even if ventilated by open windows (especially those on the lee side of the building).

L. If outdoor temperature is below 45°F, do not operate the ventilation system any longer than needed. Noticeable odors are good indicators of the need to operate the fan or open outdoor dampers. Flushing out the building until odors disappear will usually be satisfactory.

M. Use window ventilation where possible during mild weather. This reduces the power required for mechanical exhaust systems and also the air intake which normally balances the exhaust. Shut off supply air system when window ventilation alone is adequate.

N. Concentrate smoking areas together so that one ventilation system can serve them all. Adjust outdoor air to serve those areas and reduce all other outdoor air to systems.

O. In buildings with high ceilings, such as auditoriums which are used for short periods or intermittent operation, outdoor air is frequently unnecessary. For longer periods of light occupancy, outdoor air may still be unnecessary.

P. Operate kitchen exhaust systems intermittently throughout the day. Turn them off when they are not needed. Operate them at noon, coffee breaks and at heavy cooking times.

Q. Shut off laboratory hoods in air conditioned areas when not needed.

R. Many hoods exhaust much more air than necessary. Reduce the quantity of exhaust air from hoods in laboratories, kitchens and similar operations by closing off a portion of the hood, changing hood type from canopy to high velocity, or slowing down exhaust fans to the point just necessary to satisfy exhaust requirements.

S. Establish a ventilation operation schedule so exhaust systems operate only when they are needed most.

T. Do not reduce ventilation rate when outdoor air can be used for economizer or enthalpy cooling.

U. Minimize the amount of fresh air intake during heating season in units equipped with mixed air controllers by setting mixed air temperatures as high as space conditions will permit (usually 60°F-68°range).

V. Inspect building exterior and interior surfaces and caulk all cracks that allow outdoor air to penetrate.

W. Caulk around all pipes, louvers, and other openings which penetrate the building skin.

X. Repair broken or cracked window panes.

Y. Weatherstrip and caulk exterior doors and windows.

Z. Be certain that all operable windows have sealing gaskets and cam latches that are in proper working order.

AA. Cover window air conditioners with plastic covers in the winter unless used for heating.

BB. Install automatic closers on exterior doors. Consider posting a small sign next to each operable window and door leading to exterior or unconditioned space advising occupants to keep them closed while the building is being heated or cooled.

MODIFICATION OF CENTRAL PLANT OPERATING PRACTICES

Operational steps which can be taken to improve energy efficiency of central plants are discussed as follows:

A. Boiler Plant

1. Isolate off-line boilers: When heating demand can be met by just one boiler of a multiple boiler installation, energy can be saved by isolating boilers not in use.

2. Operate boilers efficiently: Examine operating procedures when more than one boiler is involved. It is far better to operate one boiler at 90 percent capacity than two at 45 percent capacity each. The more boilers used, the greater the waste of energy, not only by reduced boiler efficiency but by the operation of boiler auxiliaries.

3. Adjust air/fuel ratios of firing equipment: The air-to-fuel ratio must be maintained properly. If there is insufficient air, the fire will smoke, cause tubes to become covered with soot and carbon, and thus lower heat transfer efficiency. If too much air is used, unused air is heated by combustion and exhausted up the stack, wasting energy.

4. Check fuel gas analysis on periodic basis: The efficient combustion of fuel in a boiler requires burner adjustment to achieve proper stack temperature, CO_2, and excess air settings. Check settings to provide stack temperatures of no more than 150°F above steam or water temperature, but sufficient to prevent SO_2 corrosion of equipment. There should be no carbon monoxide. For a gas-fired unit, CO_2 should be present at 9 or 10 percent; for #2 oil, 11.5-12.8 percent; for #6 oil, 13-13.8 percent.

5. Reduce steam pressures and hot water temperatures: Maintain the lowest possible steam pressures and hot water temperatures which will meet space heat or process needs. Vary them in accordance with demand.

B. Chiller Plant

1. Operate one of multiple compressors and chillers at full load, rather than two or more at partial loads.

2. Improve operating efficiency by raising evaporator temperatures. Measures to increase evaporator temperatures include:

   a. Raise supply air temperature.

   b. Raise chilled water temperature.

   c. Maintain full charge of refrigerant.

   d. Maintain higher relative humidity levels in air conditioned space.

   e. Refer also to general "Air Handling and Refrigeration Equipment Maintenance" guidelines.

3. Improve efficiency of chillers and compressors by lowering condensing temperatures. Measures to reduce condensing temperatures include:

   a. Under light load conditions, when the refrigeration load is small and the ambient wet bulb temperature is likely to be low, the cooling performance of the tower will exceed the needs of the refrigeration machines. Under these conditions the cooling tower fan or fans can be cycled on and off to maintain a desired condenser water temperature, thus saving the horsepower required to drive the fans.

   b. Adjust air flow and water rates to air cooled condensers and cooling towers to produce the lowest possible condensing temperature. Generally, the savings in refrigeration power will exceed any increase in added power for condenser fans or pumps.

ELECTRIC POWER

A. General

1. Through letters, memoranda, signs, personal contact and other means, encourage all building personnel to turn off all electric equipment not in use, including portable fans, typewriters, calculators, coffee pots, etc.

2. Disconnect all unnecessary apparatus and devises. For example, ventilation fans in elevators where smoking is not permitted can be turned off.

3. Turn off equipment and devices which are not being used. For example, vending machines (in which spoilage would not be a problem) and drinking fountains can be turned off for the weekend. (You may wish to consider time controls to do the job for you. If would be feasible, then, to also turn off such devices during the evening hours.)

B. Power Transformers

1. Shade exterior transformer banks from solar radiation to prevent heat build-up and resultant losses.

2. Ventilate transformer banks to keep them as cool as possible.

3. De-energize transformers whenever possible, including:

   a. Unloaded transformers.

   b. Transformers supplying unoccupied or unused spaces.

   c. Refrigeration chiller transformer during the heating season.

   d. Heating equipment transformers during the cooling season.

   e. Heating and cooling transformers during periods of time which normally require no heating or cooling, as during spring and fall.

C. Outdoor Switchgear

1. Provide shading.

2. Remove or prune (in case of shrubbery) any obstructions which tend to diminish natural ventilation.

DOMESTIC HOT WATER

A. Reduce domestic hot water temperature

1. Reduce generating and storage temperature levels to the minimum required for washing hands, usually about 100°F.

2. Boost hot water temperature locally for kitchens and other areas where it is needed, rather than providing higher than necessary temperatures for the entire building.

3. Encourage usage of cold water detergents for laundries and laundromats and set water temperature to 70°F.

4. Refer to health and food handling codes for minimum temperature specification for areas involving health or research services.

B. Reduce the quantity of domestic hot water used

1. Adjust valves for minimum water use.

2. Insert orifices in hot water pipes to reduce flows.

3. Re-examine the need to heat an entire tank of water when only a small quantity of hot water is needed.

4. Simplify menus to reduce the need for large pots and pans that require large amounts of hot water for cleaning. Where practical use short dishwashing cycles and fill machine fully before use.

5. Reduce the number of meals served and/or serve more cold meals to reduce the hot water requirements for dishwashing.

6. In areas where water pressure is higher than a normal 40 to 50 pounds, restrict the amount of water that flows from the tap by installing pressure-reducing valves on the main service. Do not reduce pressure below that required for fire protection or for maintaining adequate pressure on the top floor for flushing.

7. Refer to plumbing codes, if applicable, for hotwater supply requirements.

8. Encourage off-peak hot water use to reduce system energy demand.

C. Improve the efficiency of the storage and distribution systems

1. Where forced circulation of hot water is used, shut off the pump when the building is unoccupied. When hot water usage is light, consider using gravity circulation without the pump.

2. Flush water heater during seasonal maintenance of heating systems. Clean very thoroughly.

3. Repair leaky faucets.

4. Repack pump packing glands of recirculation hot water heaters to reduce leaking of hot water.

5. For boilers with immersion tankless domestic hot water coils, make sure boiler water covers coils.

ELEVATORS

A. Reduce the number of elevators in service during hours when the majority of persons are not leaving or entering the building.

B. Turn off the motor-generator set located in the elevator machine room when not in use.

C. Encourage occupants to walk up and down stairs instead of using the elevator.

IMPROVEMENT OF MAINTENANCE PROCEDURES

A. General

1. Maintain log of maintenance and operation on all equipment.

B. Refrigeration and Control Equipment

1. Circuits and Controls

a. Inspect moisture-liquid indicator on a regular basis. If the color of the refrigerant indicates "wet," it means there is moisture in the system. This is a particularly critical problem because it can cause improper operation or costly damage. A competent mechanic should be called in to perform necessary adjustments and repairs immediately. Also, if there are bubbles in the refrigerant flow as seen through the moisture-liquid indicator, it may indicate that the system is low in refrigerant. Add refrigerant if necessary.

b. Use a leak detector to check for refrigerant and oil leaks around shaft seal, sight glasses, valve bonnets, flanges, flare connections, relief valve on the condenser assembly, and at pipe joints to equipment, valves and instrumentation.

c. Inspect equipment for any visual changes such as oil spots on connections or on the floor under equipment.

d. Inspect the liquid line leaving the strainer. If it feels cooler than the liquid line entering the strainer, it is clogged. If it is very badly clogged, sweat or frost may be visible at the strainer outlet. Clean as required.

e. Observe the noise made by the system. Any unusual sounds could indicate a problem. Determine cause and correct.

f. Establish normal operating pressures and temperatures for the system. Check all gauges frequently to ensure that design conditions are being met. Increased system pressure may be due to dirty condensers, which will decrease system efficiency. High discharge temperatures often are caused by defective or broken compressor valves.

g. Inspect tension and alignment of all belts and adjust as necessary.

h. Where applicable, lubricate motor bearings and all moving parts according to manufacturer's recommendations.

i. Inspect insulation on suction and liquid lines. Repair as necessary.

C. Compressor (Centrifugal)

1. Look for unusual compressor operation such as continuous running or frequent stopping and starting. Either may indicate inefficient operation. Determine the cause and, if necessary, correct.

2. Observe the noise made by the compressor. If it seems to be excessively noisy, it may be a sign of a loose drive coupling or excessive vibration. Tighten compressor and motor on the base. If noise persists, call a competent mechanic.

   Check all compressor joints for leakage. Seal as necessary.

3. Inspect instrumentation frequently to ensure that operating oil pressure and temperature agree with manufacturer's specifications.

D. Air Compressor

1. Efficiency of air compressors can be improved by following these guidelines:

   a. Inspect all connections for air leaks using a soap solution. Seal as necessary.

   b. Note operation. If compressor seems to run excessively, it could be a sign of pressure loss at the controls or somewhere in the piping system. Determine cause and correct.

   c. Inspect air pressure in supply tank and pressure regulator adjustment in supply line for proper limits.

d. Check belt tension and alignment.

e. Inspect air compressor intake filter pads and clean or replace as necessary.

f. Lubricate electric motor bearings according to manufacturer's recommendations.

E. Air-Cooled Condenser

1. Keep fan belt drive and motor properly aligned and lubricated.

2. Inspect refrigeration piping connections to the condenser coil for tightness. Repair all leaks.

3. Keep condenser coil face clean to permit proper air flow.

4. Determine if hot air is being by-passed from the fan outlet to the coil inlet. If so, correct the problem.

F. Evaporative Condenser

1. Inspect piping joints and seal all leaks.

2. Remove all dirt from the coil surface by washing it down with high velocity water jets or a nylon brush.

3. Inspect air inlet screen, spray nozzle or water distribution holes, and pump screen. Clean as necessary.

4. Use water treatment techniques if local water supply leaves surface deposits on the coil.

5. Follow guidelines for fan and pump maintenance.

G. Watercooled Condenser

1. Inspect condenser tubes annually or more often if experience proves it necessary.

2. Clean condenser shell and tubes by swabbing with a suitable brush and flushing out with clean water. Chemical cleaning also is possible, although it is suggested that a water treatment company be consulted first.

H. Cooling Towers

1. Perform chemical testing of water to determine if solid concentrations are being maintained at an acceptable level. This should be done daily.

2. Maintain drift eliminations in good condition to keep water loss from drift at a minimum.

3. Regulate water blowdown to the minimum consistent with water treatment and condition.

4. Check overflow pipe clearance for proper operating level.

5. Check fan by listening for any unusual noise or vibration. Inspect condition of V-belt. Align fan and motor as necessary.

6. Follow guidelines for fan maintenance.

7. Keep the tower clean to minimize both air and water pressure drop.

8. Clean intake strainer.

9. Determine if there is air by-pass from tower outlet back to inlet. If so, by-pass may be reduced through addition of baffles or higher discharge stacks.

10. Inspect spray filled or distributed towers for proper nozzle performance. Clean nozzles as necessary.

11. Inspect gravity distributed tower for even water depth in distribution basins.

I. Chillers

1. Chillers must be kept clean. Inspect on a regular basis. Clean as necessary.

2. Inspect for evidence of clogging. A qualified mechanic should be called in to service equipment in accordance with manufacturer's specifications.

J. Absorption Equipment

1. Clean strainer and seal tank on a regular basis.

2. Regularly check unit vacuum. If vacuum is low, there may be air in the unit.

3. Check purge unit operation. Purge unit removes air and other noncondensing gases from machines. If purge operates continuously and vacuum is low, shut down and check for leaks.

4. Regularly check lithium bromide solution level, add as needed, maintain correct lithium bromide level.

5. Lubricate flow valves on a regular basis.

6. Follow manufacturer's instructions for proper maintenance.

K. Self-Contained Units (windows and through-the-wall units, heat pump, ect.)

1. Clean evaporator and condenser coils.

2. Keep air intake louvers, filters, and controls clean.

3. Keep air flow from units unrestricted.

4. Caulk openings between unit and windows or wall frames.

5. Check voltage. Full power voltage is essential for proper operation.

6. Follow applicable guidelines suggested for compressor, air-cooled condenser, and fans.

L. Heating Equipment: There are numerous kinds of heating systems installed in existing office buildings and retail stores. Common maintenance guidelines to improve efficiency of operation include the following:

1. Boilers (General)

a. Keep a daily log of pressure, temperature, and other data obtained from instrumentation. This is the best method available to determine the need for tube and nozzle cleaning, pressure or linkage adjustments, and related measures. Variations from normal can be spotted quickly, enabling immediate action to avoid serious trouble. On an oil-fired unit, indications of problems include an oil pressure drop, which may indicate a plugged strainer, faulty regulating valve, or an air leak in the suction line. An oil temperature drop can indicate temperature control malfunction or a fouled heating element. On a gas-fired unit, a drop in gas pressure can indicate a drop in the gas supply pressure or malfunctioning regulator.

b. Inspect boilers for scale deposits, accumulation of sediment, or boiler compounds on water side surfaces. Rear portion of the boiler must be checked because it is the area most susceptible to formation of scale. (Scale reduces the efficiency of the boiler and possibly can lead to overheating of furnace, cracking of tube ends, and other problems.

c. Fireside of the furnace and tubes must be inspected for deposits of soot, fly-ash, and slag. Fireside refractory surface also must be observed. Soot on tubes decreases heat transfer and lowers efficiency. If gas outlet temperature rises above normal, it can mean that tubes need cleaning. Evidence of heavy sooting in short periods could be a signal of too much fuel and not enough air. Adjustment of the air/fuel ratio is required to obtain clean burning fire.

d. Inspect door gaskets. Replace them if they do not provide a tight seal.

e. Note firing rate when log entries are made. Realize that even a sharp rise in stack temperature does not necessarily mean poor combustion or fouled waterside or fireside. During load change, stack temperatures can vary as much as 100 F in five minutes.

f. Inspect stacks. They should be free of haze. If not, it probably indicates that a burner adjustment is necessary.

g. Inspect linkages periodically for tightness. Adjust when slippage or jerky movements are observed.

h. Observe the fire when the unit shuts down. If the fire does not cut off immediately, it could indicate a faulty solenoid valve. Repair or replace as necessary.

i. Inspect nozzles or cup of oil-fire on a regular basis. Clean as necessary.

j. Check burner fan blades for collection of dirt. Clean as necessary.

k. Check burner firing period. If it is improper, it could be a sign of faulty controls.

l. Clean mineral or corrosion build-up on gas burners.

m. Inspect all boiler insulation, refractory, brick-work, and boiler casing for hot spots and air leaks. Repair and seal as necessary.

2. Boilers (Fuel Oil)

a. Check and repair oil leaks at pump glands, valves or relief valves.

b. Inspect oil line strainers. Replace if dirty.

c. Inspect oil heaters to ensure that oil temperatures are being maintained according to manufacturer's or oil supplier's recommendations.

3. Boilers (Coal-Fired)

a. Inspect coal-fired stokers, grates and controls for efficient operation. If ashes contain an excessive amount of unburned coal, it is probably a sign of inefficient operation or defective equipment.

4. Boilers (Electric)

   a. Inspect electrical contacts and working parts of relays and maintain a good working order.

   b. Check heater elements for cleanliness. Replace as necessary.

   c. Check controls for proper operation. Adjust as necessary.

5. Central Furnaces, Make-up Air Heaters and Unit Heaters

   a. All heat exchanger surfaces should be kept clean. Check air-to-fuel ratio and adjust as necessary.

   b. Inspect burner couplings and linkages. Tighten and adjust as necessary.

   c. Inspect casing for air leaks and seal as necessary.

   d. Follow guidelines suggested for fan and motor maintenance.

6. Radiators, Convectors, Baseboard and Finned-Tube Units

   a. Inspect for obstructions in front of the unit and remove whenever possible. Air movement in and out of convector unit must be unrestricted.

   b. Air will sometimes collect in the high points of hydronic units. It must be vented to enable hot water to circulate freely throughout the system; otherwise the units will short cycle (go on and off quickly), wasting fuel.

   c. Heat transfer surfaces of radiators, convectors, baseboard, and finned-tube units must be kept clean for efficient operation.

7. Electric Heating

   a. Keep heat transfer surfaces of all electric heating units clean and unobstructed.

   b. Keep air movement in and out of the units unobstructed.

   c. Inspect heating elements, controls and, as applicable, fans on a periodic basis to ensure proper functioning.

   d. As appropriate, check reflectors on infrared heaters for proper beam direction and cleanliness.

   e. Determine if electric heating equipment is operating at rated voltage as necessary.

   f. Check controls for proper operation.

M. Humidification and Dehumidification Equipment

To maintain peak operating efficiency, the following maintenance guidelines should be followed:

1. Remove lint and dust periodically from air dampers, fan parts, spray chamber and diffuser, controls starter and eliminator.

2. Check equipment for carry-over. Carry-over may be maintained by adjusting eliminator seal gap, altering damper position or changing air velocity.

3. Follow guidelines suggested for "Fan and Motor Maintenance."

N. Air Handling Equipment

Proper maintenance of air handling equipment can significantly improve its efficiency. Proper maintenance guidelines include:

1. Know proper fan speed and system pressure, volume and temperature conditions. Make daily checks to maintain these conditions.

2. Inspect ductwork for air leakage. Seal all leaks by taping or caulking.

3. Inspect ductwork insulation. Repair or replace as necessary.

4. Utilize ductwork access openings to check for any obstructions such as loose hanging insulation (in lined ducts), loose turning vanes and accessories and closed fire dampers. Adjust, repair or replace as necessary.

5. Inspect damper blades and linkages. Clean, oil and adjust them on a regular basis.

6. Inspect air valves in dual duct mixing boxes to ensure full sealing and minimum air leakage.

7. Inspect mixing dampers for proper operation. Adjust as necessary.

8. Clean or replace air filters on a regular basis. Maintain pressure drop across filters within preselected limits.

9. Inspect air heating, cooling and dehumidification coils for cleanliness. Coils must be kept clean by using a mixture of detergent and water in a high pressure (500 psig) portable cleaning unit.

10. Inspect for leakage around coils or out in the casting. Seal all leaks.

11. Inspect all room air outlets and inlets (diffusers, registers and grills). They should be kept clean and free of all dirt and obstructions. Clean and remove obstructions as necessary.

12. Inspect air washers and evaporative air cooling equipment for proper operation. Clean damper blades and linkages if so equipped. Inspect nozzles and clean as necessary.

13. If electronic air cleaners are installed, check them regularly for excessive accumulations on the ionizing and grounding plate section. Replace filter media if necessary. Follow manufacturer's written instructions whenever adjustment or maintenance is required.

14. Inspect humidifier/dehumidifier air dampers, fan parts, spray chamber, diffuser, controls, strainer and eliminator. All must be kept free of dirt, lint and other foreign particles. Clean eliminator wheel by directing a high pressure stream of water between blades.

15. Adjust all VAV (variable air volume) boxes so they operate precisely. This will prevent overheating or overcooling, both of which waste energy.

16. Follow guidelines suggested for "Fan Maintenance."

O. Prime Movers--Motors, Engines and Turbines

Proper maintenance of motors, engines and turbines can greatly improve operational efficiency and reduce energy consumption. The following maintenance guidelines are suggested:

1. Motors

a. Check alignment between motor and equipment. Align and tighten as necessary.

b. Check for loose connections and bad contacts on a regular basis. Correct as necessary.

c. Keep motors clean.

d. Eliminate excessive vibrations.

e. Lubricate motor and drive bearings on a regular basis. This will help reduce friction and excessive torque which can result in overheating and power loss.

f. Replace worn bearings.

g. Tighten belts and pulleys.

h. Check for overheating. It could be an indication of a functional problem or lack of adequate ventilation.

i. Balance three-phase power sources to motors. An imbalance can create inefficient motor operation and use more energy.

j. Check for overvoltage or low voltage condition on motors. Correct as necessary.

2. Engines

a. Follow manufacturer's recommended maintenance procedure.

b. Check fuel consumption and compare with design fuel consumption.

c. Record and check cooling water temperatures daily. If cooling water temperatures exceed manufacturer's recommendations, check temperature controls and correct as necessary.

3. Turbines

a. Follow manufacturer's recommended maintenance procedures.

b. Record steam pressure and check speed daily.

c. Check oil level, packing leakage, governor and throttle valve operation regularly.

d. Record and check bearing temperatures.

e. Record and check oil cooler temperatures.

f. Check vibrations weekly.

P. Fans and Pumps

Proper maintenance of fans and pumps can greatly improve operational efficiency and eliminate unnecessary energy consumption. The following maintenance guidelines are suggested:

1. Fans

a. Check for excessive noise and vibration. Determine cause and correct.

b. Keep fan blades clean.

c. Inspect and lubricate bearings regularly.

d. Inspect drive belts. Adjust or replace to ensure proper operation. Proper tensioning of belts is critical.

e. Inspect inlet and discharge screens on fans. They should be kept free of dirt and debris at all times.

f. Inspect fans for normal operation.

2. Pumps

a. Check for packing wear which can cause excessive leakage. Repack to avoid water wastage and shaft erosion.

b. Inspect bearings and drive belts for wear and binding. Adjust, repair, or replace as necessary.

Q. Hot and Chilled Water Piping

Proper maintenance of hot and chilled water piping will improve the efficiency of the piping system. Guidelines for effective maintenance of piping systems include:

1. Check for leakage at joints.

2. Check flow measurement instrumentation for accuracy. Adjust, repair or replace as necessary.

3. Inspect insulation of hot and chilled water pipes. Repair or replace as necessary. Be certain to replace any insultation damaged by water. Determine source of water leakage and correct.

4. Inspect strainers. Clean regularly.

5. Inspect heating and cooling heat exchangers. Large temperature differences may be an indication of air binding, clogged strainers or excessive amunts of scale. Determine cause of condition and correct.

6. Inspect vents and remove all clogs. Clogged vents retard efficient air elimination and reduce efficiency of the system.

R. Steam Piping

Proper maintenance of steam piping will, among other things, prevent unnecessary wastage of steam. Effective maintenance procedures include:

1. Inspect insulation of all mains, risers and branches, economizers and condensate receiver tanks. Repair or replace as necessary.

2. Check automatic temperature-control system and related control valves and accessory equipment to ensure that they are regulating properly in various zones--in terms of building heating needs, not system capacity.

3. Inspect zone shut-off valves. All should be operable so steam going into unoccupied spaces can be shut off.

4. Inspect steam traps. Their failure to operate correctly can have a significant impact on the overall efficiency and energy consumption of the system. Several different tests can be utilized to determine operations.

   a. Listen to the trap to determine if it is opening and closing when it should.

   b. Feel the pipe on the downstream side of the trap. If it is excessively hot, the trap probably is passing steam. This can be caused by dirt in the trap, valve off stem, excessive steam pressure, or worn trap parts (especially valve and seats). If it is moderately hot--as hot as a hot water pipe, for example--it probably is passing condensate, which it should do. If it is cold, the trap is not working at all.

   c. Check back pressure on downstream side.

   d. Measure temperature of return lines with a surface pyrometer. Measure temperature drop across the trap. Lack of drop indicates steam blow-through. Excessive drop indicates that the trap is not passing condensate. Adjust, repair or replace all faulty traps.

5. Inspect all pressure-reducing and regulating valves and related equipment. Adjust, repair, or replace as necessary.

6. Inspect condensate tank vents. Plumes of steam are an indication of one or more defective traps. Determine which traps are defective and adjust, repair or replace as necessary.

7. Check accuracy of recording pressure gauges and thermometers.

8. Inspect pump for satisfactory operation, looking particularly for leakage at the packing glands.

9. Correct sluggish or uneven circulation of steam. It usually is caused by inadequate drainage, improper venting, inadequate piping or faulty traps and other accessory equipment.

10. Correct any excessive noise which may occur in the system to provide more efficient heating and to prevent fittings from being ruptured by water hammer.

11. Check vacuum return system for leaks. Air drawn into the system causes unnecessary pump operation, induces corrosion and causes the entire system to be less efficient.

WATER

A. Turn off laboratory and other water-consuming equipment when not in use.

B. Inspect water supply system and repair all leaks.

C. Check closely for percentage of make-up water in power plants. Monitor boilers for make-up water; investigate changes of 5 percent or more.

D. Check pump packing glands for excess leakage. Repair as necessary.

E. Adjust the rate of bleed-off from cooling towers according to water test results.

F. Regularly calibrate instruments that automatically control the bleed-off rate.

G. Improper sprinkling of shrubbery and lawn areas can waste water. Consult local nurserymen for proper procedure, frequency, time of day and amount of water necessary.

H. Flow of apparently clean water into drains should be investigated. Consider reusing this water.

I. Where practical, disconnnect refrigerated water fountains.

TRANSPORTATION

A. Encourage enforcement of the maximum speed of 55 miles per hour for all vehicles.

B. Replace standard-size vehicles with compact cars wherever possible.

C. Organize a car pool with central coordination by campus volunteers or paid staff.

D. Adjust carburetors for leanest fuel mixture.

E. Keep engines in fine tune through regular preventive maintenance.

F. Urge departments or schools to consolidate local trips for package pickup system if volume warrants.

G. Consolidate field trips.

H. Charge people in car pools reduced parking fees.

I. Encourage use of campus bus system.

J. Prohibit anyone living within six blocks of campus from parking on campus.

K. Start Wednesdays-are-for-walking program.

L. Put "Conserve Fuel" stickers on automobile dashboards.

M. Explore use of three-wheel motor carts or electric or propane vehicles for physical plant personnel on campus. Post office may have surplus vehicles for sale.

N. Follow octane requirements specified in vehicle manuals. Higher octane than specified is inefficient.

O. Make sure tires are inflated to manufacturer's specifications and that wheels are aligned.

P. Do not leave vehicle idling while making pickup or delivery calls.

Q. Encourage drivers to avoid jack rabbit starts and sudden stops.

R. Reduce services requiring gasoline-powered vehicles.

MODIFICATION OF OPERATING PRACTICES OF KITCHEN AND CAFETERIA AREAS

A. Turn off infrared food warmers when no food is being warmed.

B. Inspect refrigeration condensers routinely to ensure that they have sufficient air circulation and that dust is cleaned off coils.

C. Inspect and repair walk-in or reach-in refrigerated area doors without automatic closers or tight gaskets.

D. Train employees in conservation of hot water. Supervise their performance and provide additional instruction and supervision as necessary.

E. Avoid using fresh hot or warm water for dish scraping.

F. Keep refrigeration coils free of frost build-up.

G. Clean and maintain refrigeration on water chillers and cold drink dispensers.

H. Reduce temperature of or turn off frying tables and coffee urns during off-peak periods.

I. Preheat ovens only for baked goods. Discourage chefs from preheating any sooner than necessary.

J. Run dishwasher only when it is filled.

K. Cook with lids in place on pots and kettles. It can cut heat requirements in half.

L. Thaw frozen foods in refrigerated compartments.

M. Fans that cool workers should be directed so they do not cool cooking equipment.

N. Consider using microwave ovens for thawing and fast-food preparation whenever they can serve to reduce power requirements.

SECTION II: REFIT AND SYSTEMS CONVERT

Refitting and converting of existing systems requires the expenditures of capital funds. This may involve major changes in systems design. These additional energy consumption reduction measures usually yield an additional 20 to 25 percent energy savings in addition to those savings created by quick action projects.

Refit measures usually depend heavily on expert engineering analysis and careful study of proposed modifications in order to ensure cost effective use of capital.

Consultants

Refit analyses or studies may be undertaken using the in-house engineering and energy management expertise of an institution. Often, however, limited staff availability and capability, as well as the complex nature of the systems being analyzed for refit modifications, require an institution to obtain outside guidance and advice. There are many excellent engineering and energy management consultants available but there are also a growing number of "energy experts" emerging on the scene who in fact have little experience and knowledge of the problems faced on the modern campus.

If outside assistance is sought for an energy management program, consider these suggestions in order to help ensure that the type of guidance which will be most beneficial is received. The consultant should:

- Provide a report
- Prepare plans and specifications
- Assume engineering responsibility
- Provide a monitored completion report of results actually obtained.

When a consultant is brought in to conduct work, it is suggested that his services be utilized on an evolutionary basis.

A. Have the consultant make an energy survey and provide a detailed report indicating recommended energy conservation modifications, the estimated or metered amount of energy presently consumed in the building(s), and the predicted energy savings for each proposed modification. This survey and report would then be followed by predicted payback periods for each proposed modification or modifications recommended.

B. Proceed with implementing modifications. Instruct the consultant to prepare plans and specifications or work orders.

C. Have the consultant assume engineering responsibility for proper selection of revised fan drives, provision of new air balance figures for revised CFM deliveries to various spaces, and for revision of design air and liquid balance data.

D. As a final step, ask the consultant to provide a monitored completion report showing revised system design, completed air and liquid balance results, new operating instructions and updated as-built drawings showing all changes made to the system.

Energy use should then be monitored regularly to provide data used to compare actual energy reductions achieved with those predicted in the original energy conservation report.

It should also be noted that problems experienced as a result of these modifications should be made known to the consultant so that he can assist with any corrective measures which may become necessary.

Unlike most quick action measures, refit modifications require capital investment. Since there is a limit on the amount of money available at any given time, it is necessary to be particularly sensitive to the need for establishing priorities. The criteria used to establish such priorities should reflect the particular circumstances and situations existent at an institution. In most cases, it has proved beneficial to concentrate efforts on those measures which provide substantial energy savings with rapid payback. The systems most often targeted for refit based on this criterion are those which operate 24 hours a day and, in particular, those which are inherently wasteful of energy, such as dual duct and terminal reheat systms which use high-velocity air distribution, as well as those systems which have excessively high fan horsepowers and static pressures.

Some of the refit measures which have proven to be effective for colleges and universities are summarized as follows:

- Add zone demand reset controls
- Implement air volume reductions
- Use outdoor air for cooling
- Replace inefficient outdoor air dampers
- Recirculate exhaust air as practical
- Isolate off-line boilers
- Isolate off-line chillers
- Reduce transmission heat losses and gains
- Modify lighting controls, fixtures and space characteristics

These measures are listed in order of general priority but, of course, circumstances at an institution may require a different order of measure implementation.

Add Zone Demand Reset Controls to Modify Terminal Reheat and Dual Duct Systems

Terminal reheat and dual duct systems use excessive amounts of energy. The quick action measures for achieving energy consumption reduction involve manual control. It should be noted, however, that several control manufacturers have pre-engineered electronic and pneumatic controls which can do the same work.

In a terminal reheat system the zone requiring the least amount of reheat is found by comparing a signal from each zone to a reference point. Until this zone is found, the supply air temperature to the reheat coils is progressively increased. When the reference point is reached, less demanding zones continue to use just enough reheat to satisfy the individual zone control. In this case, some reheating will occur well into the summer because of system diversity. Not all of the zones peak simultaneously. Nonetheless, by cooling only far enough to meet the most demanding zone, reheating is minimized.

In a dual duct system both cold deck and hot deck temperatures are controlled to meet the most demanding cooling and heating zone. Presumably, there will be only one zone which will equal the "full cooling" reference signal. Until the most demanding zone control signal equals the reference, the cold deck air temperature is progressively increased.

In a similar fashion, a "full heating" reference is established to determine the hot deck temperature. The lowest hot deck temperature which will meet the load in the most demanding zone is found. Under summer conditions, the hot deck temperature is reset so low that it becomes unprocessed "return air".

Compared with a non-reset, dual duct system, deck temperature resetting can potentially save 10 percent of the total utility cost for a building.

Variable Volume

A terminal reheat or dual duct system can be modified also by converting it to a variable volume. Conversion or partial conversions to variable volume can reduce: air-moving energy and horsepower requirements, the amount of outdoor heating and cooling air needed and the amount of simultaneous heating and cooling used. Upwards of 50 percent energy reduction can be achieved through full conversion to a variable volume system when compared with dual duct or terminal reheat systems.

Certainly on all high pressure, high horsepower systems where air movement may account for 20 to 40 percent of the total energy used by the system, variable volume conversion should be investigated. A general rule of thumb would be to say that buildings with more than one horsepower per 1,000 gross square feet of floor space will be likely candidates for conversion.

Conversion to a variable volume system is accomplished by adding variable volume boxes and fan controls which reduce the amount of air flowing into any zone in accordance with zone load supply. This approach usually is a bit more complex than the simple addition of zone demand reset controls and, accordingly, can be somewhat more expensive. Nonetheless, variable volume has many advantages which should be given careful consideration.

In summary, variable volume systems:

A. Provide only that quantity of air required to meet a dual load.

B. Reduce outdoor air heating and cooling requirements.

C. Provide for reduced partial load operation of fans through the use of inlet vanes.

D. Reduce air flow which thereby reduces fan power.

E. Eliminate the need for control heat or reheat to interior spaces.

F. Reduce air supplied during heating mode for exterior zones up to 50 percent.

G. Provide maximum response potential for reducing energy use in accordance with actual building loads and diversity.

Add Zone Demand Reset Controls for Multizone Systems

A multizone system heats and cools several zones--each with different load requirements--from a single central unit. A thermostat in each zone controls dampers at the unit which mix the hot and cold air to meet the varying load requirements of the zone involved. As with the dual duct systems, multizone systems can also be refitted with zone demand control systems.

Each individual zone thermostat transmits a signal indicating the difference between the actual temperature in the zone or space and the thermostat setting for that zone or space. The signal is then transmitted to two places. First, it goes to the individual damper control or zone actuator which, based on the temperature differential involved, controls the dampers for the zone or space involved. The signal also goes into an electronic device called a discriminator network which compares the signals coming in from all zones. The temperature of the cold deck is then determined by the amount of cooling required by the zone or space which needs the most cooling. Likewise, the temperature of the hot deck is determined by the zone which needs the most heat. These two zones are called critical zones and the amount of heating or cooling employed is a direct function of the magnitude of the heating or cooling demand in the critical zones.

Energy is saved in this refit modification because deck temperatures are varied according to need rather than remaining constant and wasteful.

Implement Air Volume Reduction

Reduced lighting levels in a space results in reduced cooling requirement for this space which, in turn, provides potential for reducing the supply air volume of the air handling unit. Reduced supply air volume will lead to savings in the energy required for heating and cooling the air as well as the energy required for fan motors. Air volume reductions can be achieved either by changing fan motor sheaves or by using vortex dampers.

When lighting modifications are made along with other operational changes which affect ventilation supply and exhaust air volume, substantial savings of energy will result since fan brake horsepower varies with the cube of the air volume. For example, if you cut back air quantity by 10 percent, fan power input is reduced by 27 percent. In many cases, this type of modification can provide not only the most substantial energy savings but also a very fast payback.

Use Outdoor Air for Cooling

Consider installation of economizer cycle controls. "Economizer cycle" is defined as the use of cooler outdoor air beyond ventilation requirements instead of mechanical refrigeration to chill air. In many conventional air conditioning systems compressor operation can be discontinued when the outdoor temperature falls below the design supply temperature, normally 50°-60°F. Traditionally, the changeover to any economy cycle occurs when outside air reaches a temperature of approximately 55°F. At this temperature both the indoor design temperature and the humidity level within the occupied space can be maintained. In most building systems, however, it usually is economically feasible to use outside air for cooling whenever the total heat content (or enthalpy, defined by dry bulb and wet bulb temperatures) of the outside air is less than that of the return air.

It should be noted, however, that an economizer cycle requires the continuous use of a return air fan on the HVAC system involved. Thus, if it will be necessary to install a fan in order to go on an economizer cycle, careful consideration should be given to the additional expense and use of energy the fan installation would cause.

There are many other factors which also should be considered when using outdoor air for cooling:

- Type of system installed
- Climate
- Building occupancy patterns
- Zoning

Replace Leaky Outdoor Air Dampers

Many ventilation systems, especially rooftop units, were initially constructed with low-quality air dampers which do not permit accurate control. In some cases, even when dampers are fully closed, air leaks are found in quantities which exceed minimum outdoor air requirements. Leaky outdoor air dampers should be replaced with high-quality, opposed blade dampers with air seals at the blade edges and ends.

If economizer cooling is used in summer, the outdoor air dampers must be sized to pass the full volume of the supply fan. If, however, economizer cooling is not contemplated and minimum quantities of outdoor air will be used year-round, then the size of the outdoor air intake louvers and damper can often be reduced and the unused portion of the outdoor air inlet blanked off.

Recirculate Exhaust Air Using Activated Carbon Filters

Air that is exhausted must be replaced or "made up" by outside air. Make-up air must be conditioned by a mechanical system, a process which requires energy.

One method for reducing the energy that is consumed in make-up conditioning involves the reuse of exhaust air by recirculation. This recirculation of exhaust air can be facilitated by installing activated carbon filters which eliminate odors from the air. A filter would be used in the case of air recirculation from such areas as kitchens and dining rooms.

Before proceeding with this type of modification, be certain to check local codes and code authorities to ensure that the modification is permissible since this type of modification will not be useful or permissible in many laboratory areas where the nature of certain experiments does not allow the reuse of air.

Isolate Off-Line Boilers

Light heading loads on a multiple boiler installation are often handled by one on-line boiler with remaining boilers idling on stand-by. Idling boilers consume energy. Accordingly, unless an idling boiler is scheduled for imminent use, it should be secured and isolated from the heating system by closing valves, and from the stack and chimney by closing dampers.

Large boilers can be fitted with by-pass valves and regulating orifices to permit minimum flow in order to keep the boilers warm and thereby avoid thermal stress when brought on line again. It is important to remember that prior to bringing the boiler on line again, it is necessary to reopen the closed dampers.

Isolate Off-Line Chillers

Light cooling loads on a multiple chiller installation are often handled by circulating chilled water through all chillers even though only one chiller needs to be operating--or on line. This procedure wastes pump energy by maintaining an unnecessarily high rate of water flow through the system. In addition, because of the fact that water still flows through off-line chillers--an action known as the by-pass effect--the remaining on-line chiller must produce chilled water at lower temperatures in order to offset the temperature increase which results when water flowing through the off-line chillers mixes with the low temperature water coming from the on-line chiller. By installing isolating valves off-line chillers can be isolated and chilled water flow rate reduced. Also, unnecessary chilled water pumps can be deactivated to lighten load.

If multiple chilled water pumps are not installed, consider the installation of additional pumps or a multi-speed drive on the present pump.

The following is offered as a checklist of refit and/or convert items:

A. Terminal Reheat System

1. If humidity control is not required, convert the system to variable volume by adding variable volume boxes and eliminating terminal heaters.

2. Install controls to minimize simultaneous heating and cooling if converted to reheat-variable volume.

B. Dual Duct System

1. Replace obsolete or repair defective mixing boxes to minimize leakage of hot or cold air when the respective damper is closed.

2. Provide volume control for the supply air fan and reduce capacity preferably by speed reduction when both hot deck and cold deck air quantities can be reduced to meet peak loads. Reducing heat loss and heat gain provides an opportunity to reduce the amount of air circulated.

3. When there is more than one air handling unit in a dual duct air system, modify duct work so that each unit supplies a separate zone. This provides an opportunity to reduce hot and cold duct temperatures according to shifting loads.

4. Change dual duct systems to variable volume when energy analysis is favorable and the payback in energy saved is sufficiently attractive. Do this by adding variable volume boxes and fan control.

C. Multizone System

1. Consider converting system entirely or in part to variable volume by adding terminal units and pressure by-pass and/or add fan coil units in specific areas requiring constant air volume.

2. Consider installing automatic control values which will regulate hot and cold deck temperatures according to demand. When properly installed, and with all hot deck or cold deck dampers partially closed, the control will reduce hot and raise cold deck temperature progressively until one or more zone dampers are fully open.

D. Single Zone System

1. Consider converting single zone, single duct systems to variable volume by adding variable volume boxes at each branch. Fan volume should preferably be controlled according to demand either by installing inlet guide vanes or by installing a variable speed motor.

E. Fan Coil System

1. If fan coils are not located in conditioned areas, insulate the casings to reduce heat loss/gain.

2. With three-pipe systems, set control for minimum mixing of hot and cold water. Change to two-pipe operation.

F. Variable Air Volume Systems

1. Where possible, eliminate reheat coils and set the box to full close-off.

2. If not installed, provide either inlet vortex dampers or variable speed drives such as a multispeed motor of SCR control. Fan volume will be reduced when dampers begin to close until one or more variable air volume dampers are fully opened.

G. Self-Contained Systems

1. If multiple units are involved, consider installation of centralized automatic shut-off and manual override controls.

2. If units are relatively old, consider replacing them with more efficient air-to-air heat pumps or similar units with higher equivalent efficiency rating.

H. Rebalance air supply system to provide a maximum of 1 cfm per square foot of supply air to toilet rooms and adjust the exhaust system accordingly. Refer to ASHRAE Standard 62-73.

I. Replace outdoor air dampers which leak excessively and thus do not allow accurate control. Use good quality opposed blade dampers with seals at blade edges and ends. Be certain damper motors are properly adjusted to close dampers tightly.

J. Install charcoal filters or other air treatment devices in exhaust air systems and circulate treated air back into the space to reduce the amount of outdoor air required for make up for all systems handling 2,000 cfm or more. Supply slightly more outdoor air than exhaust air to pressurize the conditioned space. It is necessary to obtain approval of code administering agencies having jurisdiction in the location of the building when reducing outside air quantities below code requirements.

K. Modify duct systems and hoods and introduce untreated outdoor or return air directly to the exhaust hood. Weigh this against changing hoods to new high velocity hoods which require less make-up air.

L. Consider installing economizer cycle and/or enthalpy controls to air handling units in offices. This will minimize cooling energy requirements by using proper amounts of outdoor and return air to permit "free cooling" with outside air when possible.

Modification of Boiler and Chiller Plants

A. Boiler Plant

1. Eliminate gas pilots and install electric pilots for boilers and furnaces.

2. Install an economizer for preheating boiler feed water.

3. Install soot blowers on all residual-oil burner systems. For new installation, select the size of multiple boiler installations so that they can be operated at 75-100 percent of rated capacity for both summer and winter load conditions.

4. Add a blower and return air duct from occupied areas and convert gravity hot air furnace to forced warm air units.

5. Modify piping as necessary to permit on-line boiler to maintain temperature in idle boilers rather than starting and stopping burner when the boiler is not needed to supply the load.

6. Install automatic draft control to shut off the breaching 30 seconds after burners go off and restart automatically 30 seconds before next firing cycle to prevent heat loss up the chimney between firing cycles. Check FIA and FM for proper safety.

7. Install additional condensate return lines to the boiler for fee water systems where uncontaminated condensate is being wasted. Where condensate is being wasted, consider installation of heat exchanger to preheat domestic hot water.

8. Install and maintain proper steam regulators to reduce steam consumption. Bypasses should be used only during emergencies and during repair of regulators. On large installations, install flow meter and record changes so that an operator can analyze and maintain maximum efficiency.

9. Install an interlock between combustion air unit and burner operating with proper prestart and after-firing control to reduce the amount of cold air introduced into the building for combustion.

10. Install airtroll fittings on hot water systems to vent air from the hot water piping.

11. Install fan and duct, if necessary, to utilize warm air from the ceiling of the boiler or furnace room to preheat combustion air.

12. Fit a "shell-head" adapter to the end of the gun of oil burners firing No. 2 oil to increase combustion efficiency.

13. Regulate electric heating elements in steps or stages rather than full-on, full-off staging controls. Limit the demand on the electric supply system and eliminate wasteful override.

14. For condensate pump systems use heat exchangers to reclaim waste heat and reduce the temperature of the condensate and prevent cavitation in the condensate pump.

15. Use automatic viscosity controls on fuel oil systems for purposes of attaining best atomization for efficient combustion. This control also permits flexibility of mixing and use of any grade fuel oil, either distillate or residual.

16. Analyze loads and seasonal operating efficiency. Replace inefficient heating equipment with new modular-sized equipment to permit efficient operation at all partial load conditions.

17. When replacing obsolete #6 oil burners, consider air atomization instead of steam atomization to improve performance and efficiency.

18. Flash evaporation of boiler blowdown to recover heat or useful steam.

B. Chiller Plants

1. Raise evaporator temperatures and suction pressure.

   a. Isolate off-line chillers.

   b. If in parallel, investigate repiping chillers in series.

   c. When adding additional capacity for expansion and, where possible, in existing systems, use blow-through air-handling units rather than draw-through.

   d. Install sensing control to raise supply air temperature when load permits. This will raise chilled water temperature and evaporator temperatures.

2. Lower the condensing temperature.

   a. Modify exhaust ductwork to discharge cooled air from the building into the air intake of air-cooled condensers or cooling towers.

   b. Install sensing controls to permit cycling of cooling tower fans under light load conditions when refrigeration load is small and ambient wet bulb temperatures are low.

   c. Adjust fan blade pitch or fan speed of cooling towers for minimum power input.

   d. Install baffles in cooling towers and air-cooled condensers to reduce or eliminate by-pass of hot air around coils.

e. Modify condenser water by-pass around cooling towers to reduce condenser water temperature to the lowest level compatible with the refrigeration machine.

f. Replace air-cooled condensers with cooling towers.

g. Fit capacity controls to existing refrigeration equipment where possible and when replacing units purchase those with four steps of capacity control.

3. Use well water, ground water, sea water or lake water, if the temperatures of the water from these sources is lower than the wet bulb ambient temperature in the case of cooling towers and the dry bulb temperatures in the case of condensers.

4. Install controls to permit refrigerant migration on large systems to obtain refrigeration effect without power input to the chiller.

5. Use piggyback absorption systems to produce additional chilled water when existing centrifugal chillers are steam turbine driven.

6. When replacing absorption refrigeration equipment, compare the performance of new high temperature absorption units with new low-temperature, low-pressure, low-energy absorption units and select one based on best seasonal performance. (The former can be considered only where high pressure boilers already exist. Where high pressure boilers exist, analyze turbine-driven equipment vs. absorption.)

7. For expansion or modification, consider the use of standby diesel engines and generators, or new diesel engine-driven refrigeration equipment to reduce the electric loads. Consider using waste heat from the engines for other useful work.

8. Convert straight compressors and chiller systems to heat pump operation by adding additional condensers and evaporators and/or repiping as required.

MODIFICATION OF DISTRIBUTION SYSTEMS

A. Hydronic Systems

1. Install insulation on all hot and chilled water pipes, fittings and valves passing through unconditioned spaces to minimize heat losses and heat gains.

2. Replace fine mesh strainer baskets with ones having the largest practical openings to reduce pressure losses.

3. Remove orifice plates not regularly used for flow measurement.

4. Balance hydronic systems to attain minimally satisfactory temperature and water flow.

5. Trim impeller to actual size required on pump curve after terminal unit flows are reduced to the minimum. This will enable reductions of power requirements of actual load.

6. Install flow measurement instrumentation where none now exists. (Factory-assembled pipe-mounted instrumentation can easily be cut into the system.)

7. Check sizing of valves, filters and pipe sections. All of those which are undersized should be replaced.

8. Check all pipe fittings. Replace those which are inefficient.

9. Consider adding a parallel small GPM pump to handle heating load for dual temperature changeover systems.

10. Consider adding a variable speed drive. Although this will conserve energy, it will limit the pump's ability to handle flow to the farthest terminal units.

B. Steam Systems

1. Install insulation on all mains, risers and branches, economizers, water heaters and condensate receiver tanks where none now exists.

2. Add additional shut-off valves for more efficient zone control.

3. Install recorder pressure gauges and thermometers to enable continual monitoring of the system.

4. Modify equipment as necessary to recover heat from condensate now going to the sewer. Such reclaimed heat can be used to heat a portion of the building or to preheat water being supplied to the domestic hot water heater or can be returned to the boilers.

C. Air Distribution Systems

1. Test, adjust and balance entire air distribution system in accordance with methodology suggested in the latest ASHRAE Handbook and Product Guide.

2. Insulate all ductwork carrying conditioned air through unoccupied spaces with at least 1-1½-inches of fibrous insulation or its thermal equivalent.

3. Reduce system resistance to air flow to a minimum by replacing those duct sections and fittings which impose unnecessary resistance on the system, replacing dirty filters with adequately sized filter media which have high efficiency and low air flow resistance. Remove unnecessary dampers and other obstructions from ductwork and replace high resistance inlets and outlets with modern grilles and diffusers providing low resistance.

4. If air volume has been decreased to effect energy savings, determine resulting load on the fan motor. If it is less than 60 percent of name plate rating, consider replacing motor with a smaller one.

Reduce Transmission Heat Losses and Heat Gains

Buildings lose heat during the heating season and gain it during the cooling season through the process of transmission.

The energy required to offset heat transmission losses and gains can be substantial. It may be advisable to have a infra-red survey conducted which will help indicate where transmission heat losses and gains are occurring, and which losses and gains are more severe than others.

There are a variety of different measures which can be taken to offset transmission heat losses and gains. The two most commonly applied measures involve the use of insulation and solar controls. Note, however, that the cost of these types of modifications can be substantial and paybacks may vary widely. Thus, like all refit measures, these types of modifications should be preceded by a thorough engineering study.

The following is offered as a check list of refit items:

A. Consider using an expandable enclosure for delivery ports. It reduces infiltration when in use because it can be adjusted to meet the back of a truck and reduce substantially the amount of air which otherwise would infiltrate.

B. Install tight-fitting storm windows.

C. Consider utilizing revolving doors for the front entrance. Studies have shown that such devices allow far less air to infiltrate with each entrance or exit. Use of revolving doors in both elements of a vestibule is even more effective. If high-peak traffic is involved, swinging doors can be used to supplement revolving doors.

D. Consider installation of a vestibule for the front entrance of a building. It should be fitted with self-closing weatherstripped doors. It is critical that sufficient distance between doors is provided.

E. In locations where strong winds occur for long durations, consider installing wind screens to protect external doors from direct blast of prevailing winds. Screens can be opaque, constructed cheaply from concrete block or can be transparent, constructed of metal framing with armored glass. Careful positioning is necessary for infiltration control.

F. Seal vertical shafts and stairs from the rest of the building to reduce infiltration. Check with local fire codes to assure compliance.

G. Add insulation

1. Walls

a. If remodeling or modernization is contemplated, consider adding insulation to all exterior walls as well as those which separate conditioned and nonconditioned spaces. Refer to ASHRAE Standard 90-75 for wall insulation guidelines.

b. Give priority to walls in spaces that are continuously occupied for the greatest length of time.

c. Check all codes before installing insulation on the interior surface of the building. Some insulation materials are not acceptable because of to low ignition temperatures and/or toxic or poisonous fumes when burned.

d. When blowing insulation into a masonry wall cavity or stud space, the cavity should be completely filled under slight pressure since fill insulation often settles with time.

e. Provide vapor seal on the exterior surface of insulation when it is applied to the exterior surface of the wall. Provide vapor barrier on the room side of insulation when the insulation is applied to the interior surface of exterior walls.

2. Floors

a. Add or improve insulation under floors and over garages or other conditioned areas.

b. Insulate slab-on-grade floors that are subject to condensation or that have low surface temperatures.

c. Insulate slab-on-grade floors with edge insulation and protect insulation with a waterproof seal.

d. Where suspended floors are over a closed-in, but unused, space, apply insulation to the underside of the floor. If, however, there may be some future use for the space, or if it contains pipes and ducts, then apply insulation to the inside walls of the space leaving the floor uninsulated.

3. Roofs

a. Consider adding roof deck insulation, especially if your building is older than 20 years. Refer to ASHRAE Standard 90-75 for roof insulation guidelines.

b. If priorities to insulate roofs are necessary, then insulate a 15'-0" wide bank around the perimeter, rather than the entire roof. The roof area over the perimeter zones experiences the greatest heating load.

c. If the ceiling void is used as a return air plenum, insulation applied to the underside of the roof should be bonded or sealed to prevent migration of fibers and should not extend over the lighting fixtures.

d. If possible, include an air space between insulation boards and the underside of the roof to gain added insulating effect.

e. When adding insulation, provide vapor barriers of sufficient impermeability to prevent condensation on the interior surface of the roof.

H. Modify fenestration (windows, doors, skylights, etc.)

1. Where windows are subjected to high winds in the winter and to sunlight in the summer, consider prefabricated sunscreen on the exterior of the window. Sunscreens serve a dual purpose: They minimize the effect of heat loss due to wind and reduce solar heat gains in the summer.

2. Install thermal barriers whenever unoccupied hours exceed 70 per week and heating degree days exceed 4,500.

3. Install storm doors in all locations where degree days exceed 3,000 and provide not more than 50 percent glass area in the storm door.

4. Where exterior doors are not used during the heating season and are not required as fire exits, caulk the doors, seal them with removable strips, or insulate the areas between the storm door and the existing door, although double windows or storm doors are not cost effective to reduce cooling loads alone, and are not recommended for that purpose alone. When installed to reduce heat loss they will also reduce heat gain to a smaller extent in the summer.

5. Install temporary plastic shade cover over windows to reduce conduction loss and reduce infiltration rates.

6. Where operable storm sash is desired, provide hopper type windows with 25 percent of the total sash operable, or sliding windows, casement windows, or double-hung windows to most nearly match existing windows, if matching is an architectural consideration

7. In new additions, minimize the amount of glazing area on the north facade. Where energy required for heating exceeds that for cooling, use minimal glazing.

8. In new additions, where energy for cooling exceeds the amount of energy required for heating on a seasonal basis, minimize the amount of glazing in the west first, then east, south, and north exposures in that order.

9. In new additions, where the outdoor air conditions are close to desired indoor conditions for a major portion of the year, do not caulk or install double glazing, and provide the greatest amount of operable windows to permit natural ventilation and cooling.

I. Reduce solar heat gain through windows and glass doors

1. Consider installation of horizontal fixed or movable eyebrows over south facing glass. Install fin sunscreens on the exterior to east, west, and south facing windows to reduce solar heat gain and wind loads in the winter. In locations where winds are minimal in the winter and/or existing construction and aesthetics preclude locating sunscreens on the exterior, install them on the interior surface of the window. Screens can be hinged to permit easy access to operable windows. Sunscreens tend to reduce available day lighting for illumination.

2. Install awnings over windows to block out summer sun. Awnings are particularly suitable to shade large display windows

3. Consider installation of storm windows.

4. Consider replacing single clear glass on east, west and south facades with reflective glass when replacing broken windows if the windows are in direct sunlight 200 hours or more during the cooling season. Replace all single glass on west, east, south facades if windows are in direct sunlight 500 or more hours per year during the cooling season. Reflective glass is more effective in reducing heat than heat absorbing glass.

5. Use opaque or translucent insulating materials to block off and thermally seal all unused windows.

6. Apply reflective coatings to the inside surface of east, west and south facing windows which are exposed to direct sunlight.

7. If double windows are added to reduce heat loss in the winter, provide the inner layers with reflective glass to reduce transmission at peak conditions to 50 percent of maximum.

8. Install milium-lined drapes, venetian blinds or shutters on the inside of all south, east and west facing windows which are subject to direct sunlight in the cooling season and/or exposed to a large expanse of sky. These devices are not as effective as external shading devices or sunscreen, but are less expensive to install.

9. Refit skylights in the same manner as windows.

Modify Lighting Controls, Fixtures and Space Characteristics

In many cases existing lighting systems were designed without prior knowledge of how the space to be lighted would be used once the building was complete. This has often led to over-illumination, inconvenient placement of controls, lack of adequate controls, and specification of lamps and fixtures which--by today's standards--do not lend themselves to energy efficiency. Over-illumination and lamp inefficiency can be handled by a variety of quick fix measures which were discussed earlier, as well as by some refit measures outlined here as follows:

Controls:

- Install switches enabling deactivation in unoccupied areas.
- Install time switches for areas of light occupancy.
- Install photo-cells or timers for exterior lighting.
- Install neon pilot lights to indicate lights on in adjacent, enclosed areas.

Fixtures:

- Replace incandescent fixtures.

Surface Characteristics:

- Apply light colored or reflective surfaces to ceilings and walls.
- Lower height of partitions where possible.

The following checklist may be helpful:

a. Replace louvers and lenses and install lenses to give better quality and more efficient lighting on tasks. Lenses should be selected for low brightness and high efficiency.

b. Remove all louvers and lenses in areas where coefficient of utilization will be improved and the additional glare can be tolerated. Where lenses are necessary to control glare, use efficient type.

c. Provide manual switches or photo-cells to shut off lights when available daylight is adequate to replace the required lighting.

d. Install additional switches to permit shutting off lights in unoccupied areas.

e. In areas where occupancy is light or erratic, install time switches which automatically turn off lights at a preset time and which require manual switching to energize the lights again after that time.

f. Install photo-cells or electric timers to shut off outdoor parking lot lighting at night, during weekends, and at other times when the lot is not in use. Schedule operation of photocells and electric timers to the working shifts of employees.

g. Install neon pilot lights to alert personnel that lights are on in adjacent totally enclosed areas.

h. Replace incandescent fixtures with more efficient fluorescent or other more efficient fixtures, depending upon application.

i. When replacing fixtures, select that type with higher coefficient of utilization.

j. Replace all incandescent parking lighting with mercury vapor HID lamps.

k. Remove display lighting fixtures in retail stores, bulletin boards and other areas where inefficient incandescent lamps are used. Substitute fluorescent fixtures only where required.

l. Paint or apply light reflective colors on interior room surfaces to increase inter-reflectances and improve the performance of both natural and artificial illumination. Walls should be first in priority, then ceiling and floors.

m. Where partitions cannot be removed entirely, install low partitions, perhaps with transparent material to the ceiling, to reduce light absorption while permitting the use of "borrowed" light from adjacent spaces.

n. When refurnishing, select lighter colored furnishings that do not have a glossy surface.

o. Use air extract fixtures to redistribute captured heat from interior zones to perimeter zones to supplement heating requirements.

p. Consider installing a master switching system, using low voltage switching to permit an operator at one or more stations to turn off all lighting at the end of occupied periods. Seven-day timers can also be used to automatically program lights.

q. Modify existing fixtures to accommodate higher efficiency lamps. For instance, convert incandescent lamp fixtures to high intensity discharge (HID) lamps or convert existing HID lamps to newer or more efficient ones.

r. When undertaking alterations, use open landscape planning to the greatest extent possible. This will reduce the amount of lighting energy which would be absorbed by walls.

s. When retrofitting a building, lower the fixture mounting height.

t. Install multi-level ballasts and integral switches to reduce lighting levels.

Central Control Systems

A central control system provides constant surveillance of a building and makes efficient and effective use of physical plant systems and personnel.

These systems are usually applicable to the larger, more complex buildings or groups of buildings on a campus where energy use is high due to extended occupancy or use of special equipment.

Central control systems vary from the relatively simple types designed to perform a few functions to the progressively more complex types performing a variety of complex functions.

A central control system should be tailored to the present requirements of the facilities and systems it will control. An overview of the central control system capacity should, however, be made at the time of initial design to incorporate provisions for the expansion of system hardware and software capacity when investment money permits.

An initial system may be composed of a control console and central processing unit with one single printer output programmed only to perform start/stop and simple reset functions. Optimization of system operation would probably occur manually at the central console based on decisions made by the operating staff. By judicious use of this capability, engineering staff will be able to operate most systems from a central console. Any physical plant critical alarm will be reported automatically at the console. The operator will then be able to scan the system in alarm, analyze the fault and dispatch the correct maintenance personnel to make repairs. Maintenance alarm summaries will be available on demand and will allow work scheduling and maximum use of maintenance personnel.

In addition, a central control system can be programmed to:

- Monitor for off-normal conditions
- Monitor all fire alarm and security devices
- Monitor operating conditions of all systems and reschedule set points
- Monitor selected portions of systems and store information
- Limit peak electrical demand
- Optimize operation of all systems

A. Executive Program: This program is essential for the function of the computer itself as it keeps track of real time, controls the priority of signal processing, directs information in and out of memory, controls the operation of all associated hardware and encodes/decodes incoming and outgoing signals. An essential part of this program is the orderly shut-down of the computer on power failure to ensure that all information is safely stored in permanent memory before power is lost. Beware of systems that store information in a memory which is damaged by power failure.

B. Start-Stop Program: This is the simplest type of program; yet, with modifications, it becomes the most effective energy saver, particularly when used in conjunction with other programs and routines.

In its most simple form a start-stop program is arranged to start and stop equipment according to a predetermined schedule. The program can also open and close dampers, turn lights on and off and reset temperatures for occupied and unoccupied situations.

In this program, manual override can be provided with automatic reversion to program control at the end of an occupied or unoccupied period.

Interface with other programs allows the basic program to be overridden and equipment turned on and off to handle changing situations.

Start sequences can be arranged in a "cascade" manner to avoid simultaneous starting of many pieces of equipment thereby avoiding the cumulative effect of inrush currents which cause a high peak electrical demand.

C. Load Shedding Program: This program is used in conjunction with the start/stop program to override normal operation and to turn off equipment as a predetermined peak load value is approached. In its simplest form, the program would shut down selected equipment according to the measurement of peak load. The program can be modified to include a rolling priority feature. This feature allows equipment to be shut down on an assigned priority basis for a predetermined period of time after which it is returned to service and a lower priority piece of equipment turned off. The rolling priority would only be activated when a predetermined peak load value is approached, and the equipment turned off would be limited to that necessary to make certain that the load remains below a given level.

Interface of this program with an electrical profile routine allows development of a continuous profile of electrical demand and calculation of predicted load in the immediate future. This predicted load would then be used to initiate the rolling priority sequence in order to alter the slope of the prediction curve.

The current maximum peak load experienced in the previous eleven months would also be held in memory and used as the criterion for load shedding. This value could be constantly modified based on monitored information.

D. Optimizing Programs: These programs tend to be more sophisticated than the others so far described, requiring interface with an arithmetic routine to allow optimum settings to be calculated. The optimizing program interfaces with the start/stop program, load shedding program and reset program to modify operation of equipment.

Optimizing programs can provide economizer cycle control of outdoor air according to enthalpy and loads. Chilled water and boiler water temperatures can also be modified to provide optimum equipment operation according to load.

Certain optimizing programs are available from the manufacturer's library but others may have to be custom written.

E. Reset Programs: These programs are designed to reset the control points of thermostats and pressure controllers, and to interface with load shedding and optimizing programs. In place of, or in addition to, turning off equipment for load shedding and energy conservation, loads can be trimmed; i.e., if a peak load is approaching, space conditions can be reset to reduce cooling or heating loads; outdoor air dampers can be reset, also in this type of program.

F. Alarm Programs: These programs report alarms generated either outside the computer (fire alarm pull boxes, boiler high pressure, etc.) or in computer software. Upper and lower limits can be set in software for any monitored point. An alarm will go off when these limits are reached.

Alarm programs also can be interfaced with the start/stop program to monitor hours of equipment run, reporting a maintenance alarm when a designated number of running hours is reached. Information on particular maintenance required can be stored in memory and can be printed out when the alarm is reported.

One word of caution: Sophisticated computer control systems are not substitutes for a well-planned program of quick fix and refit measure implementation. The computer should not be used until there are sufficient understanding and manual control of existing systems. A central computerized control system will not transform an energy-inefficient campus into an efficient user of energy.

ADJUSTMENT AND MODIFICATION OF AUTOMATIC CONTROLS

A. Check operation of entire heating/cooling control system, including control valves and dampers. Correct all improper operations.

B. Check control system for instrument calibration and set point, actuator travel and action, and proper sequence of operation.

C. Inspect and calibrate pressure controls on dual duct system to obtain minimum static pressure during low demand. This will also reduce leakage.

D. Adjust controls to prevent simultaneous operation of heating and cooling systems to achieve desired temperature.

E. Limit the use of reheat to areas where humidity control is needed because of equipment needs. This can permit raising chilled water temperature.

F. Add controls to allow 100 percent shut-down of air and water to unoccupied space.

G. Inspect locations of thermostats. Relocate if they currently are positioned near outside walls, in areas that are seldom used, or if they are subject to outside drafts.

H. Consider installation of key-lock plastic covers over thermostats to prevent building occupants from adjusting settings.

I. Consider replacing pilots of gas-burning equipment with electric ignition devices.

J. Install thermostats for control of all heating equipment.

K. Consider installation of night set-back and morning start-up controls which enable scheduling heating and cooling operations for each zone on the basis of occupancy patterns. A consultant may be required to determine when start-up should take place to ensure comfort for occupants when they arrive for work.

L. Consider installation of program clocks and manual overcall timers in control circuits to enable savings through scheduled operation of fans, refrigeration equipment, heating equipment, and so on. Additional economies may result from decreased costs of labor and maintenance.

M. Consider adding an automatic draft damper control to reduce heat loss through breeching when the gas or oil burner is not in operation.

N. Consider installation of automatic door closers on swinging doors leading to the exterior. Also consider such devices for garage and loading platform door operations.

O. Consider adding time clocks on self-contained heating and cooling units for automatic shut-off.

P. Consider adding a step-controller to electric heating systems with resistance elements to permit staging. This may result in more effective heat control and demand management.

Heat Reclamation Systems

Heat reclamation is the recovery and utilization of heat energy that would otherwise be wasted. Waste heat can be substituted for a portion of the heat energy that would normally be required for heating, cooling, and domestic hot water systems. Heat recovery conserves energy, reduces operating costs, and reduces peak loads.

There are a variety of different devices which can be utilized to reclaim waste heat.

Rotary Heat Exchanger

The rotary heat exchanger uses a heat transfer medium in the form of a cylindrical drum or wheel.

When the cylindrical drum is rotated slowly between the supply air stream and the exhausted air stream, it absorbs heat from the warmer air stream and rejects heat to the cooler air stream. While the supply and exhaust ducts must usually be located near each other in order to use this system, close proximity can occasionally be an obstacle, especially when exhaust streams are contaminated. In these cases, purge sections must be added to the wheel and special filtration may be necessary in the supply air stream.

Air-to-air Exchangers

Air-to-air heat exchangers transfer heat directly from one air stream to another through direct contact on either side of a metal heat transfer surface.

Run-around-coil System

A run-around-coil system is composed of two or more extended surface fin coils installed in air ducts and interconnected by piping.

The heat exchanger fluid, consisting of ethylene glycol and water, is circulated through the system by a pump, removing heat from the hot air stream and rejecting it into the cold air stream. A run-around-coil system may be used in winter to recover heat from warm exhaust air for use in preheating cold outdoor air and in summer to cool hot outdoor air by rejecting heat into cooler exhaust air.

The coil type exchanger has the advantage of permitting heat transfer between supply and exhaust systems in widely separated portions of a building, since coils are installed in each of the intake and exhaust ducts and are connected only by piping. It is relatively easy to run piping for long distances through a structure, interconnecting a number of separate exhaust and fresh air systems to form one complete system.

Heat Pipe Systems

Heat pipes are composed of extended surface finned tubes extending between adjacent air ducts.

The tubes run continuously from one duct to the other, and they are on the same horizontal plane. Each tube contains liquid refrigerant which evaporates at the warm end of the tube absorbing heat from the warm air stream. The evaporated refrigerant then migrates as a gas to the cold end of the tube where it condenses and releases heat into the cold air stream. The condensed liquid then runs back to the hot end of the tube to complete the cycle. To operate effectively, the heat tubes must slope down from the cold end to the hot end and accurate control of the slope must be provided.

Heat pipes running between hot and cold air ducts can be used only when ducts are immediately adjacent to each other and thus some modification of existing ductwork may be necessary for installation of this type of system.

Shell and Tube Heat Exchangers

Shell and tube heat exchangers can be used to exchange heat in the following configurations:

A. liquid-to-liquid,

B. steam-to-liquid, and

C. gas-to-liquid.

All three configurations are commercially available in a wide range of sizes and outputs with reliable heat exchange data.

A particularly favorable application of these exchangers involves the capturing of energy from hot condensate or from hot refrigerant gas, condenser water and hot drain lines from kitchens and laundries.

Incinerators

Incinerators burning solid waste produce 6,000 BTU/lb of common trash. Special heat recovery incinerators are now available in sizes down to approximately 100 lbs/hr burning rate which generate about 450,000 BTU/hr. Typical applications are absorption refrigeration, heating, domestic hot water, etc.

All local, state and federal air pollution standards must be strictly complied with and environmental impact statements are required when using these systems.

Waste Heat Boilers

Waste heat boilers are used in conjunction with high temperature heat recovery such as that generated by engine exhaust. Such systems can also be used in conjunction with the exhaust given off by gas turbines which can then be used to drive refrigeration equipment or electric generators.

Solar Energy Utilization

Solar energy obviously has tremendous potential because the energy is free. Unfortunately, the systems required to harness that energy are not free. In fact, the cost of these systems in past years has kept solar energy more in the concept stage than in a practical application stage. Now that the cost of energy has risen so dramatically, however, the cost of solar energy systems has become more realistic. The fact that the energy source involved--the sun--is both infinite and pollution-free is an additional incentive for investigating and using these systems.

At present, solar energy systems are used primarily for hot water heating and, to a lesser extent, for space heating.

Hot Water Heating

One typical solar hot water heating system consists of flat plate collectors, storage tank, controls and circulating pump.

The solar collector is the heart of the system. It uses direct and diffused energy from the sun to heat the water. Usually it is necessary to have one square foot of collector for each gallon of hot water used by the system. The thermal performance of the system usually depends on five factors:

- Climatological and meterological conditions
- Solar collector size, design, and construction
- Orientation of collector and tilt angle with the horizontal
- Size of storage tank
- Temperature of domestic hot water

Space Heating and Cooling

The four key components of a solar heating system are collectors, piping and/or ducts, storage capacity, and controls, the number of collectors required varies with the climate where the system is being used. The collector area usually ranged from 20 percent to 50 percent of the total building floor area in order to provide 20 percent to 70 percent of the annual heating requirements.

Piping or ducts are required to connect the solar collectors with the storage tank and the installed HVAC system. Proper insulation is required to keep thermal losses to a minimum.

The storage system is usually a metal or concrete tank. In general, two to five gallons of storage are required for each square foot of collector area.

The control system for the solar system operates the circulating pumps which divert warm water from one storage tank to another, or directly to the load. In addition to the pumps, there must be fans in an air system to blow air through the collectors or storage in response to climatic conditions and building load.

The existing heating system of a building determines the type and size of solar collection system required. In most cases, however, significant modifications are required to enable a satisfactory interface.

Although utilization of solar energy has been given a great deal of publicity, the possibilities for its use on a campus must be studied very carefully.

Systems convert options must be very carefully studied and analyzed prior to implementation.

First of all, many of the systems convert modifications involve new technologies which are in the developmental stage. Each day brings new revelations and improvements on such systems and thus the potential obsolescence of currently available systems must be carefully weighed.

Secondly, systems convert modifications usually involve a substantial amount of investment. It is important to consider not only the cost of the equipment needed, but also the cost of the associated changes which are likely as a result, including new duct work, new partitions, controls, and so on.

Domestic Hot Water

A. Reduce the Consumption of Domestic Hot Water

1. Reduce the cold water pressure with an automatic control valve. Do not set lower pressure than needed to flush toilets on top floors or for pressures required for fire protection.

2. Install flow meters on cold water lines supplying the water heater when hot water consumption is more than 3,000 gallons per day.

3. Install flow restrictors in the supply branch to groups of taps when existing faucets have flow rates greater than 1-½ gpm.

4. Install spray type faucets that use only ½ gpm instead of 2 or 3 gpm.

5. Install self-closing faucets on hot water taps.

6. For new additions, install foot-operated pedal valves.

7. Replace obsolete kitchen equipment such as dishwashers with new ones that have minimal water requirements.

8. Consider flow regulators in showers.

B. Reduce the Temperature of Domestic Hot Water

1. When the majority of domestic hot water usage is at lower temperatures install an electric, gas or small oil-fired boiler to boost the temperature for kitchens, laundries or processes requiring higher temperatures. Consult code authorities for minimum allowable temperatures for commercial kitchen use.

2. Further reduce water heater temperatures during unoccupied periods such as shut-downs or vacations.

C. Reduce the Thermal Loss from Hot Water Piping, Appurtenances, Storage Tanks and Hot Water Generators

1. Insulate hot water storage tanks when insulation is less than the equivalent of 3-inch fiberglass and/or when insulation is in need of repair.

2. Insulate hot water piping whenever there is less than the equivalent of 1-inch fiberglass.

3. De-energize hot water circulating pumps to reduce heat loss from piping within the building. Where extremely long runs require that the circulator be in operation during occupied periods, install a seven-day timer to shut off the pump automatically during unoccupied periods.

4. Insulate the exterior jacket of tankless or tank heaters which are not immersed in the hot water boiler or hot water tank.

5. When installing new storage tanks or making major modifications to a building, relocate hot water tank as close to the load as possible.

D. Increase the Efficiency of the Hot Water Generator and Equipment or Install more Efficient Equipment

1. Replace gas pilots with electrical ignition.

2. Install local hot water heating units when domestic hot water usage points are concentrated in areas distant from the central generation and storage point.

3. Repipe hot water storage tanks if the cold water make-up supply is connected to the upper half of the tank and/or if the hot water outlet from the tank is in the lower portion of the tank.

4. Install a storage water heater for summer use when the existing space heating boiler is used for hot water generation.

5. Replace electric hot water heaters with heat pumps to improve the coefficient of performance from 1 to approximately 3. Use hot drain water as a heat source for the heat pump, or use an air-to-water heat pump.

6. When hot water demands are increased because of expansion or change in occupancy and if the heating boiler has sufficient capacity and is in operation year-round for air conditioning, install a tank or tankless heater in place of a separate hot water generator. If the additional requirements for hot water are to serve facilities remote from the boiler and usage is small, install a separate heater in the cold water line directly at the fixtures rather than serving them from a central system.

CONCLUSION

Effective energy management is a critical goal if colleges and universities are to continue to provide the services for which they have been established. Valuable dollars are being lost up the smokestacks of many institutions. It is up to each institution to ensure that every possible dollar or bit of energy that can be saved is saved. This will not always be easy and it will sometimes be frustrating. However, a carefully planned evolutionary approach to energy management will certainly be a major step toward ensuring the economic and academic future of colleges and universities.

SECTION III: NEW BUILDING DESIGN

The design of new space or space to be totally remodeled shall incorporate energy conservation techniques. On May 15, 1975, Governor Robert F. Bennett issued Executive Order No. 75-6 directing that the design of state buildings shall include the consideration of energy conservation as a high priority element. The Governor further directed that the Division of Architectural Services of the Department of Administration require that an energy impact statement be included as part of the preliminary design submittal.

In order to assist associate architects to comply with the Governor's Executive Order, the Division of Architectural Services prepared and issued "A General Guide to Energy Impact Statements for State Construction." This document, printed early in 1976, has been a part of the State Architect's procedural manual and has been incorporated into each associate architect's contracts.

Because of the impact of these energy savings guidelines on our new construction we have decided to include this manual in its entirety in this section of our document. Louis J. Krueger, Director of the Division of Architectural Services, has given his permission for this following reprinting.

INTRODUCTION

At the present time, approximately 14.4% of the annual total energy used in the United States is consumed in the operation of commercial buildings. This represents the equivalent of nearly 5.5 million barrels of oil a day. If the energy used in commercial buildings were reduced by 20%, a saving equivalent to one million barrels of oil a day could be realized. In general terms most state buildings fall into the classification of commercial buildings. We are of the opinion that savings of greater than 20% can be realized in future buildings compared with buildings built just two and three years ago.

In order to reduce the energy consumption in buildings that are now being designed, realistic energy goals should be established. The future construction of man-made environment will be altered greatly as our state moves toward periods of reduced natural resources. New design responsibilities will be placed upon architects and engineers responsible for building design. It is evident that building construction will be forced to reflect design efforts that take a totally integrated approach to site, building and energy distribution systems. Efficient energy utilization can be achieved by the design of systems which can be shown to use less energy, or which can be shown to shift energy demands to off-peak periods.

Guidelines have been developed to assist administrators and designers in the development of programs and projects which will serve the needs of user agencies and meet the objectives of energy conservation.

It is the intent of the guidelines to be flexible and to encourage the Associate to develop creative and innovative solutions to energy utilization. However, the Associate will be expected to show the comparative effectiveness of the systems which are selected against those rejected for the project. The Division of Architectural Services will be reviewing the design development of the associate at each stage and will be conscious of and receptive to ways to improve operation and function of the total system to achieve an optimum level of energy conservation.

The Division of Architectural Services is firmly committed to energy conservation. This commitment must be shared similarly by the Associate Architect in the design of state-owned facilities.

Louis J. Krueger
Director

FOREWORD

As the Associate Architect becomes acquainted with the building program and develops the schematic design for the project, it will be his responsibility to justify his decisions for the various objectives contained within this guide. Such justification shall be in writing and shall be presented at or near the completion of the design development phase of the services.

Some interim justification may be requested by the Director prior to the time for filing the complete report, and generally the Associate will be making these decisions routinely as the design develops. It will be the responsibility of the Associate to establish that agreement has been reached on the first three elements contained in these guidelines: Orientation, Configuration and Building Envelope.

The final report for justification of all elements need not be in any special form or format but must show that the achievement of maximum conservation has been attained within the cost parameters and life expectancy of the project.

The report from the Associate shall outline full particulars of basic assumptions and design criteria used to develop his conclusion for heat loss, heat gain, equipment, size, etc.

The director will require some elements of minimum standards be met. An example: All buildings shall be designed using insulating glass, and will not accept alternates on the bid form for single glazed openings in order to save cost initially. Also maximum insulation shall be used in walls and roofs consistent with the function of the building. If costs must be cut to stay within the building program, such cuts shall be made in the building embellishments and methods of detailing rather than in the reduction of insulation.

ORIENTATION

The orientation of each of the four or more facades and of the roof have a unique effect upon energy consumption depending on the site. However, the constraints imposed by the site may not always give the designer total latitude to make optimum use of building orientation.

There are conflicting results on the orientation of the exterior walls of a building, particularly as they relate to the ratio of opaque wall surfaces to glass surfaces. The Associate Architect should strive for an optimum solution in relating summer heat gain to winter heat loss.

1. In developing the plans and situating the building to the site, the Associate Architect should analyze each exposure separately for:

   (a) Use of natural light to achieve:

      (1) Savings in electric utilization
      (2) Reduction in air conditioning

   (b) Heat gain by conduction in summer and winter, which results in:

      (1) Greater air conditioning load
      (2) Lesser heating load

   (c) Heat gain and loss through radiation at glass areas, which change air conditioning and heating loads.

   (d) Impact on ventilation, heating and cooling through openable sections of windows, which result in:

      (1) Less mechanical ventilation requirements
      (2) Greater infiltration
      (3) Less cooling at 55° to 75° outside temperature

2. The Associate Architect should examine the site for natural assists to environmental control problems, such as:

   (a) Microclimate
   (b) Winds
   (c) Trees
   (d) Exposure
   (e) Adjacent structures

   Any of which may dictate:

   (a) Location of entrances
   (b) Swing of doors
   (c) Use of vestibules

All of the above should be thoughtfully analyzed so that the building will be oriented for utilization of the elements.

Elements of the report:

Give a concise report explaining your reasons for arriving at the solution you are contemplating regarding building orientation. If the site is restricted by other non-flexible elements that likewise restrict your flexible, so state these restrictions.

CONFIGURATION

The configuration of a building, as well as the orientation and envelope, affect the amount of energy used. Where energy can be saved by using natural light for work tasks, then the exterior perimenter can be increased and its interior space proportionately decreased. This extension can be very limited since the increase in exterior perimeter demands more energy for heating and cooling thus offsetting the gain from energy saved from natural light.

We know that a round building has the least amount of wall envelope for the floor area contained therein when compared with other shapes such as a square or rectangle. We recognize that we would not want all buildings to be round; in fact, several factors may prohibit such planning.

The site may dictate the constraints on the shape of the building which also may help or hinder the ability of the building to take maximum advantage of sun and wind.

It is not the intent of the Director to dictate the shape of the building or to place severe restrictions on the Associate Architect in his search for the best design to fit all of the conditions he must meet. Rather it is the purpose of this element of the guidelines to alert the designer to use imagination in seeking a solution to the building configuration. All of the elements of nature must be constantly reckoned with during the life of the building, so a building which has a high proportion of exterior wall in relation to the enclosed floor area will be frowned upon as a reasonable solution to any energy conserving building.

Elements of the report:

Substantiate your selection of the contemplated configuration. State briefly why your solution is the best solution over other possible configurations.

BUILDING ENVELOPE

The building envelope, consisting of solid walls, windows, doors and other openings, roof and floor surfaces, is subjected to the ravages of variable climatic conditions by its individual orientation. The building envelope and the proportion of the elements of the envelope directly influence the heating and cooling peaks and the capacity requirements of the HVAC system.

The building envelope has little influence on energy loads due to ventilation, domestic hot water or solid waste. On the other hand, the envelope is the major determinant of the amount of yearly energy required for the building environment.

The thermal properties of the envelope determined by the combination of wall mass, thermal resistance, insulation location, exterior surface color and texture, and the type and location of glazing all affect energy consumption differently in summer and winter. Of all building envelope components, windows have the greatest effect on energy consumption by their heat gain, heat loss or in some cases, infiltration. Their use to reduce artificial lighting requirements may be a false saving when weighed against the increase in the HVAC system to counteract the heat loss/heat gain.

The "U" factor alone does not determine the yearly energy consumption for heating and cooling for each square foot of wall, but it must be considered in concert with mass, color and insulation location. A wall of high thermal inertia, subjected to solar radiation for one hour, will absorb the heat on the outside surface and transfer it to the interior over a time period of six hours. Conversely, a wall having the same "U" factor but low thermal inertia will transfer the heat more quickly, perhaps in two hours, or less.

Since windows in the building envelope may create the greatest effect in heat loss or heat gain, infiltration, natural lighting or vision and, in some cases psychological reactions still not completely understood, they should be studied with utmost care in developing the fenestration. A windowless building may solve some energy conservation problem but at the same time create more problems in fire and life safety. Conversely, excess areas of windows may not necessarily improve natural lighting or ventilation, but may compound heating/ cooling distribution problems.

The percentage of window to opaque wall area can be reduced if the window shape, placement in the wall, type of glazing, use of thermal break and use of shading devices are designed with an awareness and consideration of their combined impact on energy consumption and user needs.

The use of heat-reducing and solar-reflecting glass will generally be left to the discretion of the Associate Architect. The use of single glass in windows will not be accepted. All window glass, whether tinted, heat absorbing, reflective or clear, shall be dual glazed or insulating sealed panels.

Opaque walls for most general occupancies shall be designed with a "U" factor to achieve a low heat loss. In instances where a low "U" factor cannot be realistically achieved the Director will work with the Associate to achieve a high level of conservation consistent with the intended use of the building and extent of sophistication of the HVAC system.

Where practicable and consistent with the use of the local interior area, some windows shall be openable. Operating sash shall have weatherstripping on contact with fixed sash. Serious consideration shall be given to thermal break between inside and outside metals.

Floors consisting of concrete built on grade generally will not create excess energy consumption. However, extreme care shall be used in detailing the perimeter insulation and the protection of the floor slab from the exterior cold penetration. Another area of grave concern is the floor system built over open or unheated space such as floors over a parking garage or floors cantilevered beyond the floor below. In order to reduce the potential for cold floors in such instances, maximum insulation shall be used. Particular attention shall be given to the perimeter of such floor areas in order to reduce cold transmission to the floor directly.

Elements of Report:

The preceding section and this section may be developed together since they are so interrelated. Explain your position on the building envelope as it relates to energy conservation.

VENTILATION

Ventilation is the amount of outdoor air or treated air which is supplied for health or physiological purposes. Ventilation should be differentiated from outdoor air used for control of thermal conditions such as "economizer cycle". The amount of ventilation is a function of user desires and occupancy requirements.

The amount of oxygen required to support physical needs can be supplied usually by one to two cubic feet per minute (CFM) per capita. One to four CFM is usually ample for control of odors and very light smoking. However, the area and volume of space, the density of occupancy, and the intensity of odor may influence ventilation requirements.

Common practice frequently uses excessive amounts of ventilation at all seasons and all times of the day and night. It is particularly wasteful when spaces are ventilated all night and on weekends when the building has few or no occupants.

It is particularly important to analyze the physical requirements of the space and the users, needs and then provide only the ventilation necessary to handle those specific needs.

Selective ventilation is facilitated by carefully grouping smoking areas, toilet rooms and other areas having similar ventilation requirements. Also power requirements may be reduced by such grouping.

Considerable savings can be realized by reducing ventilation air quantities and by increasing the efficiency of the ventilation systems so that they require less energy to deliver required air. Fan and duct design low resistance filters and a building plan which permits shorter duct runs are factors which reduce air friction and blower horsepower.

Generally in most occupancies it is unnecessary to open the outside fresh air dampers supplying ventilation needs at the start of each day. The entire building volume of air is of sufficient quality to permit each occupant eight or ten CFM of satisfactory air for a period of two or three hours before introduction of outside air is needed.

Where odors may build up over night, such as in food preparation areas and laboratories, the ventilation system may be started up earlier. A monitoring device to open the outside air dampers in response to room conditions would result in better control and less energy consumption than current general practice.

To minimize infiltration, the mechanical system should be balanced so that supply-air quantity equals or exceeds exhaust-air quantities. In spite of the precautions taken to reduce air infiltration, a considerable amount of air will usually filter in. Take credit for infiltration as a part of the outdoor requirements for the building occupants and reduce mechanical ventilation accordingly.

If odor removal requires a high volume of exhaust and a corresponding intake of outside air, consider re-circulating the air through activated carbon filters, or in extreme cases through electro static filters.

Air from "clean" areas can be transferred to more contaminated areas such as toilet rooms and other areas having higher exhaust requirements instead of supplying outside fresh air for make-up.

In buildings having conditions of high localized heat generating equipment, remove the heat as the air is exhausted to warm the intake air by heat transfer coils, thermal wheels, run-around systems, etc.

These systems will add to the cost of the fixed equipment so it is the designer's obligation to weigh every additional cost of energy saving systems against the cost savings in operation and the limits of the budget.

Elements of report:

The Associate shall explain the extent of ventilation required by certain functions of the building and the ventilation desired for all functions of the building and how he proposes to provide this ventilation in the total system. If there is potential for re-using exhaust air in other sections of the building, explain how it is to be accomplished.

ILLUMINATION

Lighting is a major consumer of electrical energy in almost all types of buildings both for the power used to supply luminaires and for the energy required for the air conditioning to counteract the heat from the lights.

Total energy consumption for direct lighting in the U. S. in 1972 was slightly over 20 percent of the total electricity generated for all uses. This percentage amounts of 360 billion kilowatt hours, or 1.7 million barrels of oil per day. Of all lighting needs, commercial, public and industrial buildings account for 70 percent of the total lighting energy consumption.

Past practices frequently have confused quantity with quality. This resulted in over-lighted buildings which did not necessarily improve visual performance. Actual needs in terms of both quality and quantity should form the basis for proper lighting design.

Natural lighting can serve only perimeter areas of a building, and even with landscape planning, it cannot penetrate deeply into the interior of large areas. The amount of natural light will depend on other factors such as the time of day, weather conditions, and time of year.

Natural light saves electrical power only when the lighting is properly controlled so that perimeter areas can be turned off when natural lighting is of good quality and is properly diffused.

The use of windows and natural light must be weighed against other considerations such as additional heat required to compensate for larger windows, the more controls to distribute the heat (or cooling), the undesirable glare, and other factors.

Whenever possible, the designer should use fluorescent lamps in lieu of incandescent. In general, a fluorescent lamp will provide at least four times the lumens per watt of a standard filament lamp. In areas with higher ceilings, the designer should consider High Intensity Discharge Lamps.

Circuits serving large rooms can be arranged for 50% and 100% lighting. This will allow reduced lighting levels for periods of low use. Special switching methods and devices can save energy only if the personnel are encouraged to operate and use them. On the other hand, users cannot conserve energy unless the switching and lighting layouts allow them to do so.

The design engineer must redirect his thoughts on the amount of lighting necessary for various tasks. The design of the distribution system (substations, conductors, branch-circuit panels, etc.) should be such that some expansion can be achieved without substantial changes to the electrical systems. It would be the recommendation of the Division that the following footcandles (sustained) be followed, with minor exceptions.

TASK	FOOTCANDLE LEVEL
Normal office work such as reading, writing, typing, etc.	50 $\pm$ 10
Detailed office tasks, prolonged periods, drafting, accounting computers, etc.	70 $\pm$ 10
General purpose areas; circulation, assembly, lecture	30 $\pm$ 10
Classrooms; reading, notes, tests	50 $\pm$ 10
Laboratories; task areas laboratories	70 $\pm$ 10
General areas	40 $\pm$ 10
Areas of high critical visual need, prolonged visual tasks	80 $\pm$ 10
Hallways, corridors, vestibules and toilets	20 $\pm$ 10
Stairs	30 $\pm$ 10
Shops	30 $\pm$ 10

The footcandles are given above as the intensity recommended at desk top or work station. Higher levels require justification in terms of energy used and value received. In areas where specific tasks require higher levels, use fixtures to localize the light at the task areas.

Elements of report:

In the energy impact report the Associate shall outline basic lighting levels in major functions of the building. List the types of lighting to be used and justify levels contrary to those listed above. The Associate shall specifically address himself to decorative lighting if he intends to use any.

APPLIANCES - EQUIPMENT

Appliances and equipment are not only large users of electrical energy; they also usually generate considerable heat. This heat is sometimes difficult to dissipate or to use elsewhere, and it is expensive to reuse unless it is available in considerable concentration. Large pumps, motors, blowers, etc., also produce serious noise pollution unless the design engineer chooses the equipment with care.

The yearly energy consumed by electric power systems depends upon the magnitude and characteristics of the loads, the efficiency of the motors and equipment, the line and transformer losses and the power factor of the system. Power factor is a function of the equipment characteristics and the load factor on the electrical equipment. Power losses and corresponding energy requirements increase as the demand increases. Consider the value of reducing the size and capacity of transformers, switch-gear, conductors and motors by load leveling, off-peak operation, load shedding and matching motor sizes closely to the actual brake horsepower demand. All motors 10 HP and larger should be provided with capacitors on load side of starter with power factor correction to 95% of unity.

If a pumping system requires 45 H.P. at full capacity, determine what the demand may be on the system. It may be realistic to consider a 20 H.P. and a 25 H.P. motor installed to operate in sequence as the load demanded, instead of one 50 H.P. motor that may be "idling" a good percentage of time.

Select the equipment with care and of a size only sufficient to respond to the needs it must meet. Do not over-size air conditioning equipment, blowers, motors and other energy users just to meet the contingency of rare abnormal conditions.

Elements of report:

The Division is interested in work sheets which have been used in calculating equipment sizes. Initial costs must be weighed against operating costs and energy savings. Compare operating load on equipment and determine feasibility of smaller equipment operating in sequence wherever the opportunity exists.

HEATING, VENTILATING AND AIR CONDITIONING

The peak loads used for design conditions generally determine the size and capacity of the heating and ventilating systems. The duration of the temperature and humidity conditions, modified by wind and sun, generally determine the yearly energy consumption.

The relationship between the heating and the cooling systems is very direct. The ducts, pipes, air handling units, compressors in some cases, duct and pipe insulation, configuration of distribution runs and controls frequently serve both heating and cooling systems. Very often they are optimum for either the heating or the cooling mode; the efficiency of the other may suffer.

For optimum energy conservation, the total system must be considered, including yearly energy consumption, in the selection of equipment and mode of operation.

Whenever external elements can provide environmental control without the assistance of mechanical systems or expenditure of energy, their use should be considered. But in some cases, systems designed for natural ventilation may enjoy only brief periods of energy conservation during the year. In those cases the determination of the amount of use of the natural elements must be weighed carefully.

Some buildings may require both heating and cooling in different zones simultaneously during some parts of the year. To provide both heating and cooling in the same space is extremely wasteful and must be avoided if we are to be serious about conserving energy. The interior of a building may need cooling because of the heat generated by lights, people, business equipment and machines. At the same time heat loss occurs at the perimeter walls where heating is needed. Where planning does permit the excess internal heat to dissipate through the envelope, mechanical systems such as heat pumps, heat-of-light systems or even low pressure transfer systems may achieve this.

In some cases one may wish to consider the combination of two or more systems (within available funds) to achieve greater energy conservation. Fan coil systems can be used in conjunction with variable air volume systems, or heat pumps with variable volume systems, or single duct low velocity systems interior spaces in combination with fan coils, perimeter radiation, variable volume or others.

Generally, variable air volume systems use less energy than constant volume systems for the same system static pressure. All thermal reheating systems use more energy than alternative systems for the same system characteristics. Dual duct systems and multi-zone systems, while not as intensive as terminal re-heat systems, do have similar characteristics. They do mix hot and cold air to satisfy a thermostat setting. Excess energy is consumed when air is heated and then re-cooled, or cooled and then re-heated.

The designer is forewarned that the Division of Architectural Services will not accept a terminal re-heat system as a proper solution for an energy saving building system.

Sufficient control should be provided so that large areas need not be over-cooled or over-heated to satisfy localized specific requirements. However, several rooms with the same activity and the same exposure should not be individually controlled just to patronize one or two people using those rooms. In many cases the use of locking thermostats should be considered so that persons cannot adjust the temperature to suit eccentric tastes.

Air-handling systems, or portions of systems, delivering conditioned air (both supply and return) and installed in non-conditioned spaces, shall be thermally insulated.

The heating system should be sized so that the gross output does not exceed approximately 125% of the net heating load.

Ventilation and air-handling systems should provide the lowest energy use and operating costs to meet the design criteria of temperature, humidity and air movement for the space being served. The designer should use caution when selecting blowers so that blower noise is not a problem in occupied spaces adjacent to the equipment room. Use only as many heating zones as is economically and environmentally feasible.

Specify the equipment capacity that will operate at peak efficiency. Do not oversize cooling equipment. Recognize that the extreme conditions may occur on only a very few days out of each year, and it may not be necessary to have optimum conditions for those few days.

In large installations and in areas having large volumes of exhaust air, consider the use of heat-conversion systems.

Snow-melting systems should be held to a minimum and, when specified, should be adequately controlled to prevent their over-use.

All energy-saving systems and methods considered by the designer should recognize the building budget limitations, the long-term cost/benefit analysis and the cost of maintenance.

Elements of report:

Show design assumptions and list all figures used in determining cooling loads, heating loads and ventilating needs. If the option exists to use more than one system, compare all aspects of operating costs and energy saved by the various systems.

Study the option of using two or more systems when building configuration, occupant load or function may permit and compare energy saved in relation to initial cost.

Submit work sheets which show various design temperatures, inside and outside, used in calculating total heating or cooling load.

Show in tabular form the amount of energy needed for the various elements of the building and its contents with percentage of total of each element. This chart may show the following elements, as well as others which may be revelant.

ANNUAL ENERGY REQUIRED IN THERMS (100,000 BTU's)

Building Element	Heating	Cooling	Total	% of Total
Walls				
Roof				
Glass				
Ventilation Air				
Infiltration				
Lighting				
Occupants				

OPERATION AND MAINTENANCE

What the designer puts in the building to meet the conditions of the space has a great deal to do with operation and maintenance cost as well as energy conservation. We must recognize that maintenance and operation are important ingredients of energy savings.

In order to assure proper maintenance and operation, the mechanical and electrical systems must be designed in a manner which will permit ready access to equipment. Proper controls, pressure and temperature gauges, filter gauges, tube-pulling space, access doors, equipment rooms and adequate working space must be provided to permit proper operation and maintenance.

The control system, without over-sophistication, must respond to indoor and outdoor environmental conditions in order to program the fluid temperatures and flow quantities, fans, pumps and other equipment. Many well-designed systems are operated at 30 to 40 percent lower efficiency than they are capable of. When equipment will operate at partial capacity for considerable percentage of time, consider dual or back up equipment so that one unit will operate near capacity until conditions automatically energize the second unit.

Those units should be avoided which will require high maintenance costs of high man-hours of time for operation, regulation or re-calibration.

Elements of report:

The statistics of operation and maintenance will generally show up in other sections of the report. If, however, there is special equipment with high operating costs, the analysis of viable options should be explained.

CONCLUSION

The amount of energy needed for a given building is a direct result of early decisions in the building design. These decisions are directly related to the building envelope, amount of glass, amount of insulation, building orientation, size and shape, building plan and user needs.

The Architect, when developing the solution to the building program, should think "energy conservation" with each decision. Aesthetics must not take precedence over energy conservation designs.

At the same time the building plan is being developed, the engineer should be making determinations about the building energy systems. At each step of the decision-making process the designer should evaluate the system being considered in order to reduce the energy consumed to a minimum while still maintaining acceptable level of both physical and emotional comfort for the occupants.

The designer should search the development of innovative systems which can conserve energy. Alternate energy systems should also be considered when such systems can be developed within the budget limitations of the program.

At each step in the design development the Associate and his engineers should communicate his decisions to the Director so that no time is wasted by developing a building system that may be unsuited to the goal of reducing energy consumption.

SECTION IV: ASHRAE STANDARD 90-75

The national professional organization known as the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) has developed standard 90-75 as an energy conservation guideline for new construction. This new 50-page standard is gaining wide acceptance nationally. Copies may be obtained from local chapters of the ASHRAE or by contacting the ASHRAE Circulation Sales Department, 345 East 47th Street, New York, New York 10017.

Standard 90-75 is summarized in the following paragraphs:

Section 4.0 of the standard describes minimum requirements for the thermal design of the exterior envelope of new buildings. These requirements are not to be construed as the optimization of energy-conserving practices. Several pages of figures and tables are presented to describe the maximum heat loss allowable through various parts of the building envelope for different climatic conditions expressed in degree days. Criteria are also shown for cooling, air leakage and solar factors.

Sections 5.0 and 6.0 cover heating, ventilating and air conditioning systems and equipment. These two sections describe calculation procedures and give recommendations for indoor and outdoor design conditions. Formulae are presented for thickness of pipe and duct insulation. Tables and charts are shown for the selection and rating of HVAC systems and component parts. Coefficients of Performance (COP) are described.

Section 7.0 provides criteria for design and equipment selection that will produce energy savings when applied to service water heating including water heaters, storage tanks, boilers and piping.

Section 8.0 deals with electrical distribution systems, power factors, voltage drops and other subjects concerning the efficient distribution of electrical energy from the service entrance to the point of use.

Lighting power budgets in accordance with a given set of criteria and given calculation procedures are explained in section 9.0. This covers luminaire coefficients of utilization and other energy related items.

Section 10.0 provides for complying with Standard 90-75 by using an alternate method of energy analysis that is equal to or better than the procedure outlined in the previous nine sections of the standard. The basis of comparison is on equivalent annual energy consumption per gross square feet of floor space.

The final part of the standard, section 11.0, applies to solar, geothermal, wind or other non-depleting energy sources.